Second to None: Preserving America's Military Advantage Through Dual-Use Technology

National Economic Council • National Security Council

THE WHITE HOUSE

WASHINGTON

May 5, 1995

Ms. Margaret Brautigam
Defense Technical Information Center
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Alexandria, VA 22304-6145

Dear Ms. Brautigam:

I approve for public release on the Internet the document Second to None: Preserving America's Military Advantage Through Dual-Use Technology.

Dorothy Robyn

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Special Assistant to the President
for Economic Policy

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National Economic Council • National Security Council
Office of Science and Technology Policy

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Executive Summary

The collapse of the Soviet Union and the end of the Cold War have *not* brought an end to the need for a strong U.S. military. Instead of a potential confrontation with a global nuclear power, we find ourselves facing challenges that are different but no less complex: the spread of nuclear weapons and other weapons of mass destruction; major regional, ethnic and religious conflicts; and opposition to democratic reform in the former Warsaw Pact and the Third World. These new threats, if anything, increase the need for fast, flexible, mobile forces equipped with the most advanced weapon systems.

Technology is the key. Since World War II, U.S. military superiority has been based on our technological advantage, as was plainly demonstrated in the Persian Gulf War. Technology will be even more important in the uncertain and unstable environment we now face.

To maintain its technological advantage, the Department of Defense (DoD) must break down the barriers created over the last 30 years between the defense and civilian sectors. Because of DoD's overreliance on military specifications and because of the crush of a needlessly cumbersome procurement system, many commercial firms refuse to do business with the Department of Defense altogether, and those that do often wall off their defense production. DoD, as a result, has become *reliant on an increasingly segregated defense industrial base.*

Such a strategy is no longer appropriate for three reasons. First, as the defense budget declines, the cost of supporting a segregated defense industrial base has become prohibitive. The unit production cost of successive generations of weapon systems has increased 5 to 7 percent each year, not counting inflation, since the end of World War II. At the component level, for example, the military is paying $10 for computer chips that are virtually the same as ones being sold commercially for $1; the $9 difference is due to contractor overhead and other costs of DoD's special but often unnecessary requirements.

Second, in a number of important technologies, the defense industry is no longer in a position of technological leadership with respect to the commercial sector. In fact, the new technologies that are most critical to our military advantage—software, computers, semiconductors, telecommunications, advanced materials and manufacturing technologies—all are being driven by fast-growing commercial demand, not by military demand. DoD must get on the shoulders of these dynamic commercial industries to take full advantage of them.

Third, because of their declining market and growing isolation, defense-unique firms are not investing in new technology at rates comparable to those of commercial firms—a process that IBM's former chief scientist describes as the "ghettoization" of defense technology. Moreover, in some sectors, the rapidly shrinking defense industrial base may lack the required capacity to quickly rebuild.

Vision: An Integrated Technology and Industrial Base

As a nation, we can no longer afford to maintain two distinct industrial bases. We must move toward a single, cutting-edge national technology and industrial base that will serve military as well as commercial needs. This "dual-use technology strategy" represents a new way of doing business. Most important, it will allow the Pentagon to exploit the rapid rate of innovation and market-driven efficiencies of commercial industry to meet defense needs: By drawing on commercial technology and capabilities wherever possible—along with the superior systems design and integration skills of U.S. prime contractors—the military can do its job more effectively and at lower cost. As an additional benefit, a dual-use strategy will allow DoD's continuing investments in technology to contribute more to our nation's commercial performance and economic growth.

By using components, subsystems and technologies developed by commercial industry wherever possible, DoD should be able to attain three compatible objectives.

- **Access to leading-edge technology**: A dual-use strategy will provide access to leading-edge technology and allow the military to introduce the commercial sector's continuous stream of innovations and updates during both the development and the deployment of new weapons. This will shorten development time and increase the pace at which technological improvements are incorporated into new weapons.
- **Affordability**: Greater reliance on commercial capabilities will reduce the military's costs for procuring leading-edge technology. Commercial components, technologies and subsystems in many instances can meet DoD's functional needs at significantly lower costs than technology that is military-driven and customized.
- **Ability to rebuild**: A dual-use strategy will make it easier to build back military capabilities to a higher level, if need be. Close integration with the private sector is imperative if our nation is to be equipped to quickly gear up its capabilities.

"Dual use" in this context does not refer simply to DoD purchase of commercial off-the-shelf parts and equipment. Rather, it involves a fundamental shift toward dual-use R&D, equipment and operations. Generic technology must be consciously pushed to satisfy both civil and military needs—for lower costs and higher quality, as well as increased performance. Moreover, future weapon systems must be consciously designed to use state-of-the-art commercial parts and subsystems and to be built in integrated facilities.

To be sure, commercial technology will not work in all instances: conventional munitions and nuclear attack submarines have no commercial counterpart. But a great many defense needs can be served better and less expensively by commercial firms, facilities and technologies. Moreover, as flexible manufacturing systems are developed and more widely adopted, it will increasingly be possible to produce in a single plant both low-volume military equipment and equivalent high-volume commercial equipment.

Strategy: Acquisition Reform Plus Investment in Dual-Use Technology

Fundamental **reform of the defense acquisition system** is the essential foundation for DoD's dual-use technology strategy. At the Administration's urging, Congress passed the landmark "Federal Acquisition Streamlining Act of 1994," which will significantly improve the way the government buys $200 billion worth of goods and services a year, from software to jet aircraft. Most important, the Act makes it easier for the Defense Department (and other federal agencies) to buy commercial products and services, including state-of-the-art products that are not yet on the market.

To complement congressional reforms, Defense Secretary Perry in June announced a dramatic reversal of the Pentagon's longstanding policy toward "milspecs"—the 31,000 specifications and standards that prescribe how military items are to be made and tested, down to the most minute detail. Secretary Perry instructed the military services to use commercial (or performance-based) specifications and standards in lieu of milspecs "unless no practical alternative exists." This new policy will mean the end of the $500 coffeepot. To take a more common example, it will allow DoD to buy commercial computer chips at a fraction of the cost of milspec chips.

Acquisition reform also will help defense firms diversify into commercial markets: Many of our military contractors can compete successfully in the global marketplace, but not if they must carry the weight of all the red tape and special requirements placed on them by the government. Lifting this burden will help preserve high-paying jobs and will enhance the performance of our industrial base, which strengthens our national security and our economy.

Building on the foundation of acquisition reform, three "pillars" support DoD's new dual-use strategy by altering the department's approach to investment in technology.

First, the Pentagon is bolstering its support for **dual-use R&D**, to exploit the potential of advanced commercial technologies to meet defense needs. DoD's Advanced Research Projects Agency (ARPA) is targeting investments in focused "thrust areas"—computers and software, electronics, sensors, simulation and manufacturing—to ensure that commercial firms in this country can supply the superior technologies that will maintain our military advantage.

For example, ARPA is blazing the trail in multichip module (MCM) technology, which allows electronic systems to work faster and more reliably using less power. DoD needs MCMs for activities ranging from precision guidance of advanced weapons to real-time signal processing for intelligence activities. On the commercial side, MCMs open the door to a vast range of new and improved products including global positioning systems, real-time engine controllers for automobiles, and digital signal processors for speech and images in telecommunications. Because commercial demand will eventually make MCMs more affordable to the military, DoD benefits by accelerating the development of the technology while simultaneously ensuring that it meets defense requirements.

Another ARPA dual-use initiative aims to perform massive computing tasks—that are done today on single, central supercomputers—on multiple computers scaled for personal use. **Scalable computer architectures** (together with MCM technology) are revolutionizing information processing for civilian as well as military users. They will dramatically enhance the ability of battle-site command and control centers to process tactical information and position (or reposition) weapons systems. Similarly, because of their mobility, scalable computers will give surface ships the computing power to mount tactical missile defense, and airborne command and control centers such as JSTARS will be able to identify and track multiple targets in high-clutter environments.

The Technology Reinvestment Project is ARPA's largest and most visible dual-use program. Unveiled by President Clinton in early 1993, the TRP awards matching funds to industry-led projects, selected purely on the basis of merit, to develop new dual-use technologies that meet defense needs. The program's success to date is encouraging: for an investment of $440 million a year, the TRP has leveraged billions of dollars of R&D. A key to its success is the emphasis on partnerships: the TRP has created unprecedented linkages for technology collaboration and business partnership among defense and commercial companies, small and large firms, and universities and laboratories. A second emphasis is cost-sharing: every TRP dollar is matched by $1.33 of non-federal funds (well above the dollar-for-dollar match required by ARPA). This cost-share ensures industry's commitment to the project and lays the foundation for industry to assume the total cost of product development.

TRP projects are developing promising dual-use technologies in a range of areas:

- **Low-cost night vision**: U.S. troops will be able to "own the night," through widespread use of infrared sensors made 10 times cheaper by leveraging new commercial technology.
- **High-density data storage devices**: Vast increases in portable, low-cost data storage will give our front-line soldiers immediate access to the best information and intelligence.
- **Battlefield casualty treatment**: New sensors and information systems will greatly improve the ability to find, diagnose and treat injured combatants during the critical first hour they are down in the field.
- **Affordable composite aircraft structures**: Lightweight, polymer composites for aircraft engines will increase the performance and range of military aircraft while lowering the cost of repair and maintenance.
- **Detection of chemical and biological agents**: Sensors to detect and identify chemical and biological agents in the battlefield will protect U.S. troops from this growing threat.

In addition to ARPA, each of the military services is pursuing focused dual-use R&D to leverage commercial technology. For example, the Air Force leads the Integrated High Performance Turbine Engine Technology Program (IHPTET), which aims to double the capability of the propulsion system for aircraft and cruise missiles. Six of the seven manufacturers participating in IHPTET are active in both commercial and military aerospace markets. This facilitates the migration of technologies developed for the military into commercial products, and vice versa, and ensures that there is sufficient production capability to support future military needs.

The second pillar in DoD's dual-use strategy is **integration of defense and commercial production** to enable industry to "dual produce". The Pentagon is pursuing this goal in two ways. It is supporting efforts to transition existing defense technologies to commercial applications, in order to make those technologies more affordable and accessible to the military. At the same time, DoD is helping U.S. manufacturing firms become more flexible, so that the custom products the military needs can be produced alongside commercial versions of the same product.

To illustrate, a few years ago, DoD pursued microwave monolithic integrated circuit (MIMIC) technology as a strictly military development, but the high costs prohibited widespread defense use of the devices. MIMICs are advanced gallium arsenide semiconductors used for military radar. As part of the MIMIC program, DoD now encourages contractors to pursue commercial applications—in collision avoidance systems for automobiles, satellite communications, and air traffic control signal processing—thus creating the prospect of affordable devices for defense. A joint venture between Hughes Aircraft and Delco Electronics produces both the military device and a commercial version on the same production line, with a changeover time of less than two hours.

Another illustration is the TRP's Precision Laser Machining Project, a vertically integrated consortium of defense and commercial firms that is adapting DoD-funded diode-pumped laser technology to improve the manufacturing process for automobiles, aircraft, engines and ships. The "spinoff" of laser technology to industrial production is itself a major benefit to the DoD. For example, more precise drilling of cooling channels in aircraft engine turbine blades constructed of super alloys will allow the engines to operate 20 degrees cooler; this will double the life of military engines. In addition, the consortium's work will yield an affordable technique for eliminating atmospheric distortion of laser beams; this technique will give military aircraft a superior way to track and jam incoming heatseeking missiles.

As an example of DoD's new emphasis on flexible manufacturing, the Air Force is demonstrating the ability to produce sophisticated circuit boards for the F-22 aircraft on a high-volume production line, located in a commercial division of TRW, that also manufactures circuit boards for trucks. (Among other challenges, the Air Force has had to work around its traditional contracting procedures, which would disrupt TRW's ongoing commercial business.) The goal is to show that commercial manufacturing practices, coupled with factory flexibility, can meet military needs for functionality and durability at a cost savings to DoD of 30 to 50 percent.

As its third pillar, the Defense Department is investing in initiatives that encourage **"insertion" of commercial technologies and products in** the development, production and support of **military systems**. Although acquisition reform eliminates regulatory barriers to buying commercial, Pentagon program managers and defense contractors still face costs and risks to adopting commercial products and technologies. To offset these costs and risks, the Defense Department is actively identifying and promoting opportunities for commercial insertion. For example, DoD is working with an industry task force to identify environments in which commercial integrated circuits (ICs) packaged in plastic can be substituted for military ICs packaged in high-cost ceramic. Commercial ICs are being used now in a number of military systems, and anecdotal information suggests that they cost only a fraction as much as their milspec counterparts with no loss in performance.

Ultimately, successful insertion requires that weapon systems be designed from the outset to incorporate commercial rather than defense-unique materials, technologies and components, with cost and manufacturability treated as key considerations. One test of this "design for dual use" concept is the Tier II+ High Altitude Endurance Unmanned Aerial Vehicle (UAV) program. The UAV is designed to carry out high-altitude surveillance and reconnaissance in enemy territory even during bad weather. The goal is to provide military commanders with real-time information on the opponent's terrain and infrastructure, and on the position and concentration of enemy troops.

When DoD solicited proposals to develop the UAV, contractors were given only one absolute requirement: the plane must cost no more than $10 million. DoD specified *what* it wanted the UAV to be capable of doing—subject to the cost constraint—but it left it up to contractors to determine *how* to accomplish that. To give them the necessary flexibility, DoD used a streamlined acquisition process.

This flexibility, combined with DoD's cost ceiling and an ambitious deadline for prototype delivery, meant that contractors proposed designs that relied heavily on existing commercial technology. Most defense contractors formed partnerships with commercial companies—e.g., a manufacturer of business jet airframes. A total of 14 teams submitted proposals—a sign of industry's enthusiasm for this innovative program.

Conclusion

Since World War II, U.S. military superiority has been based on our technological advantage, and technology will be even more important in the unpredictable security environment we now face. For tecnnology to be an effective bulwark, however, we must abandon our reliance on a separate and increasingly isolated defense industrial base. We must recognize that commercial industry, not the military, is the driving force behind many advanced technologies today.

The Defense Department's new dual-use technology strategy, building on the foundation of ongoing defense acquisition reform, is designed to eliminate the artificial barriers built up over the years between commercial and defense industry. This will save billions of dollars annually in procurement costs and broaden the industrial base upon which defense can draw. Most important, it will give DoD access to advanced technologies in the commercial sector that are critical to developing future weapon systems. This dual-use strategy, coupled with continued reliance on the superior systems design and integration skills of U.S. prime contractors, should ensure a superior fighting force for decades to come.

Among other actions, the military has turned to ARPA to help find a path through this new dual-use environment. ARPA has a 37-year tradition of investment in dual-use technology to meet defense needs, leading to the development of the Internet, supercomputers and artificial intelligence. Through programs such as the Technology Reinvestment Project, ARPA—working closely with the services—is leveraging the advanced technologies and efficient production capabilities of commercial industry to keep our military the strongest in the world.

Integration of the commercial and defense industrial bases is a powerful idea whose time has come, as Defense Secretary Perry said when he turned DoD's milspec system upside down. An integrated base is clearly essential to continued military strength. Commercial-military integration also contributes to U.S. industrial performance and a stronger economy overall. No other strategy is more important to ensuring continued U.S. international superiority in a post-Cold War world.

Integrating the Commercial and Defense Sectors

The Defense Department can no longer afford the luxury of having its own private industry.

John Deutch,
Deputy Secretary of Defense
July 28, 1993

The collapse of the Soviet Union and the end of the Cold War have *not* brought an end to the need for a strong U.S. military. Instead of a potential confrontation with a global nuclear power, we find ourselves facing challenges that are different but no less complex: the spread of nuclear weapons and other weapons of mass destruction; major regional, ethnic and religious conflicts; and opposition to democratic reform in the former Warsaw Pact and the Third World. These new threats, if anything, increase the need for fast, flexible, mobile forces equipped with the most advanced weapon systems.

Technology is the key. Since World War II, the U.S. military has relied on qualitatively superior weapons systems to overcome potential opponents with a quantitative advantage. Superior U.S. technology was a key factor in the outcome of the Cold War, and it was decisive in the Persian Gulf War. It remains the foundation of post-Cold War U.S. military strategy, to deter and win regional conflicts and protect our troops in peacekeeping operations. Technology also gives us the ability to detect and deter proliferation of weapons of mass destruction.

If technology is to continue to provide our military advantage, however, we must fundamentally revise our defense technology policy. Two primary forces make this change imperative.

First, during the last several decades the defense industrial base has become more and more isolated from the national, or commercial, industrial base. This occurred both because of a military emphasis on weapon system performance over cost and because of a needlessly cumbersome, sclerotic federal procurement system that discouraged commercial firms from doing business with the Department of Defense (DoD). The Carnegie Commission on Science, Technology and Government concluded in 1991 that "in effect, the United States has two technology bases, a defense technology base and a commercial technology base."

The cost of supporting this autarkic defense industrial base has grown rapidly. The unit production cost of successive generations of weapon systems has increased 5 to 7 percent each year, not counting inflation, since the end of World War II. At the component level, for example, the military is paying $10 for computer chips that are virtually the same as ones being sold commercially for $1; the $9 difference is due to contractor overhead and other costs of DoD's special but often unnecessary requirements.

Second, in a number of important technologies, the defense industry is no longer in a position of technological leadership with respect to the commercial sector. Although DoD R&D programs continue to push the technological frontier, the pace at which that technology actually moves into production trails well behind the rapid rate of new product development by commercial industry.[1]

Moreover, the Defense Department is no longer the dominant customer for most high technology. For computers and semiconductors, for example, DoD is less than 5 percent of the U.S. market. In fact, the new technologies that are most critical to our military advantage—software, computers, semiconductors

[1]This trend is perhaps best illustrated by the commercial computer and electronics sectors, which now develop new products in three- to four-year cycles. The defense industry, by contrast, typically takes ten or more years to build a new system.

and telecommunications—all are being driven by fast-growing commercial demand, not by military demand. As one indication of this change, non-federal R&D expenditures now greatly exceed those of DoD (see Graph 1).

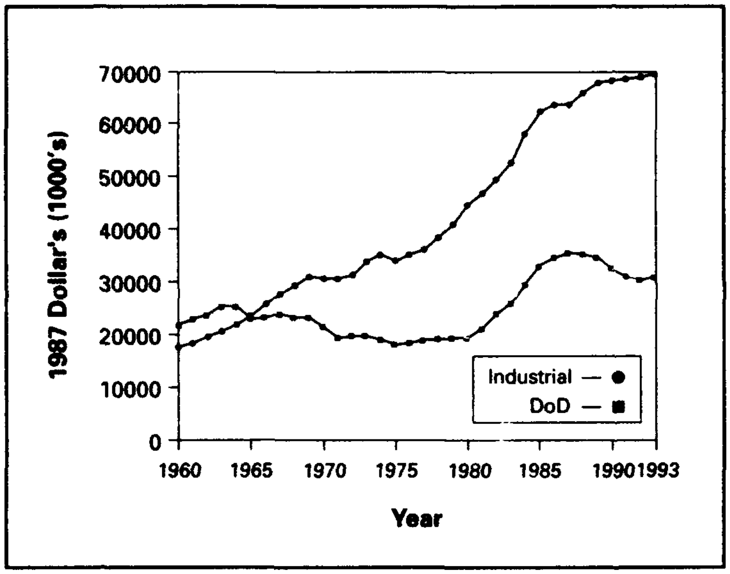
The segregation of our defense and commercial sectors is particularly inappropriate at a time of growing convergence between many of the underlying technologies that support military and commercial products. This point—often misunderstood—bears repeating. Even though defense and commercial products often diverge, many of the technologies critical to military superiority are identical to or closely allied with technologies that are vital to commercial industry, and that convergence is increasing. For example, advances in commercial electronics in the last ten years mean that the commercial technology is often as rugged and reliable as its military counterpart—and at a fraction of the cost.[2]

To be sure, commercial technology will not work in all instances: conventional munitions and nuclear attack submarines, for example, have no commercial counterpart. DoD will continue to support defense-unique technologies and capabilities wherever necessary.

But a great many defense needs can be served better and less expensively by commercial firms and facilities. Moreover, as flexible manufacturing systems are developed and more widely adopted, it will increasingly be possible to produce in a single plant both low-volume military equipment and equivalent high-volume commercial equipment.

In short, the Pentagon has become increasingly reliant on a segregated defense industrial base at a time when it most needs access to commercial industry for the advanced technologies that are critical to developing future weapons. Given the growing superiority of commercial technology, this situation would have been a problem even had the defense budget remained at Cold War levels. But with a

Graph 1[3]: Trends in DoD and Industrial R&D Expenditures, 1960-1993



declining budget—spending on weapons and supplies is down by more than half since the height of the Cold War—DoD reliance on a "defense-unique" industrial base is neither effective nor affordable.

Dual Use: A Strategy for Affordable, Leading-Edge Technology[4]

As a nation, we no longer can afford to maintain two distinct industrial bases. We must *move toward a single, cutting-edge national* technology and industrial base that will serve military as well as commercial needs. This "dual-use technology strategy" represents a new way of doing business. Most important, it will allow DoD to exploit the rapid rate of innovation and market-driven efficiencies of commercial industry to meet defense needs: By drawing on commercial technology and capabilities wherever possible—along with the superior weapon system design and integration skills of U.S. prime contractors—the military can do its job more effectively and at lower cost. As an additional benefit, a dual-use

[2]To illustrate, a new car contains a computer chip, hard-mounted to the engine block, that can meet or exceed military requirements for temperature, vibration and humidity. Moreover, the commercial chip is only one-tenth the cost of the comparable chip made to military specifications.

[3]DoD data from Office of the Comptroller, *National Defense Budget Estimates* for FY 1995, March 1994, pp. 83-85. Industrial R&D outlays from National Science Board, *Science & Engineering Indicators—1993*, Washington, D.C.: U.S. Government Printing Office, 1993 (NSB 93-1), p. 332.

[4]Dual-use technology, broadly defined, is technology that has both commercial and military applications. A technology may be developed first for a military need and then applied commercially, or vice-versa. Alternatively, commercial and military applications may be pursued in parallel.

strategy also will allow DoD's continuing investments in technology to contribute more to our nation's commercial performance and economic growth.

By using components, subsystems and technologies developed by commercial industry wherever possible, DoD should be able to attain three compatible objectives.

- **Access to Leading-Edge Technology:** Because the leading-edge technology that DoD needs resides, increasingly, in commercial firms, a dual-use strategy will provide access to critical technology and allow the military to introduce the commercial sector's continuous stream of innovations and updates during both the development and the deployment of new weapons. This will shorten development time and increase the pace at which technological improvements are incorporated into new weapons.
- **Affordability:** Greater reliance on commercial capabilities will reduce the military's costs for procuring leading-edge technology. Commercial components, technologies and subsystems in many instances can meet DoD's functional needs at significantly lower costs than technology that is military-driven and customized.
- **Ability to Rebuild:** A dual-use strategy will make it easier to build back military capabilities to a higher level, if need be. Close integration with the private sector is imperative if our nation is to be equipped to quickly gear up its capabilities.

"Dual use" in this context does not refer simply to DoD purchase of commercial off-the-shelf parts and equipment; one cannot design a weapon system and then expect to find commercial parts with which to build it. Rather, it involves a fundamental shift toward dual-use R&D, equipment and operations. Generic technology must be consciously pushed to satisfy both civil and military needs—for lower costs and higher quality, as well as increased performance. Moreover, future weapon systems must be consciously designed to use state-of-the-art commercial parts and subsystems and to be built, where possible, in integrated facilities.

Fundamental reform of the defense acquisition system is the foundation for this dual-use technology strategy. Building on this foundation, three "pillars" support the dual-use strategy by altering the approach to DoD investment in technology. They are:

1. Increased investment in leading-edge, dual-use R&D to ensure that commercial firms in this country can supply the superior technologies that will maintain our military advantage;
2. Integration of commercial and military production to enable industry to "dual produce"; and
3. Insertion of commercial products and technologies into defense systems wherever possible.

The Foundation for Dual Use: Defense Acquisition Reform

The DoD acquisition system is a web of laws and regulations adopted for laudable reasons. The aim of these laws and regulations is to ensure that competition is fair and the taxpayer is protected from waste, fraud and abuse. But the rules have led to a system that is over-regulated, inflexible and incompatible with commercial practices. The system discourages firms from doing business with DoD—resulting in fewer suppliers, less competition, and higher costs.

The consequences of this system are unacceptable. During the Persian Gulf War the Air Force placed an emergency order for 6,000 commercial two-way radios from Motorola, Inc. The Pentagon waived all military-unique specifications, but procurement officials were still legally bound to certify that the government was indeed getting the lowest available price for the product. Unfortunately, Motorola's commercial unit lacked the specialized record-keeping systems that DoD's procurement system required. In addition, because the radio was widely marketed—and because any misstatement regarding the price might be construed to constitute a felony—no Motorola official would risk making the certification. The impasse was resolved only when the Japanese government agreed to buy the radios and "donate" them as part of its promised contribution to the allied war effort.

To take a more routine example, Pratt & Whitney makes aircraft engines for military as well as for commercial customers. Although these engines incorporate sophisticated electronics, leading commercial suppliers such as Intel and Motorola will not partner with Pratt in custom technology development for the military because they are unwilling to abide by cost-accounting standards and other defense-unique procurement requirements. (Motorola has a government electronics division that adheres to these requirements, but it lacks access to the most advanced technology and production techniques found elsewhere in the company.)

To overcome these problems, DoD's acquisition system must undergo a fundamental, top-to-bottom transformation. It is not enough to fine tune the existing system. It must be thoroughly redesigned to enable DoD to reach out and take full advantage of the inventiveness and efficiency of today's dynamic commercial market.

That is a tall order, and it is fair to ask why the Clinton Administration thinks it can succeed when every previous attempt at reform has failed or fallen far short of it goals. The answer is that the declining military budget, together with the growing superiority of commercial technology, give us no other choice.

Legislative Reform

Significant changes in procurement law are necessary, if not sufficient, to redesigning the system. In October 1993, the President and Vice President called for legislation to fundamentally reform federal procurement, and the Administration worked closely with Congress to pass the "Federal Acquisition Streamlining Act of 1994". This bill—which the President signed at a Rose Garden ceremony on October 13—is landmark legislation that will significantly improve the way the federal government buys $200 billion worth of goods and services a year.

The Act provides for three key statutory changes. Most important, it makes it easier for the Defense Department (as well as other federal agencies) to buy commercial components, products and services. For example, under the new law, the Army should be able to buy radio receivers available in the commercial market without requiring special certifications from the supplier. Even receivers that have been modified, say, for the military to handle encrypted information may be treated as a commercial product, because such modifications are made for commercial customers.

Second, the reform legislation enacts streamlined contracting procedures for small purchases. Federal procurements involving less than $100,000 represent 90 percent of all procurement *transactions* but only 10 percent of all procurement *dollars*. As a result, these smaller purchases account for a disproportionate share of paperwork and red tape.

Third, the legislation authorizes DoD to undertake five pilot programs that will allow the Department to test innovative approaches to acquiring commercially derived jet aircraft, aircraft engines and other items. These cost-saving innovations are critical to our ability to meet future military needs within our budgetary limits.

See Box A for a summary of the legislation.

BOX A

Federal Acquisition Streamlining Act of 1994

The Federal Acquisition Streamlining Act of 1994 is reforming the way the federal government buys $200 billion worth of goods and services a year, from software to jet aircraft. The legislation is expected to save taxpayers $12.3 billion over five years—much of that in the Department of Defense, which accounts for two-thirds of all federal purchases. Even more important, the reforms will make it easier for DoD to get access to cutting-edge technology that is available only in the commercial sector.

COMMERCIAL PRODUCTS. The Act makes it easier for federal agencies to buy commercial components and end-items, including commercial products that are modified to meet government needs, using standard business practices.

- The new law establishes a clear statutory preference for the acquisition by agencies of commercial items rather than items specially designed for the government.
- It waives numerous laws requiring companies to provide the government with information they do not routinely collect or provide to their commercial customers.
- And it expands the scope of products and services that qualify for treatment as commercial items, thereby enhancing the government's access to components, end-items and services from the commercial sector. For example, the new law covers products that are based on evolving commercial technology but that are not yet available in the market.

By adopting commercial business practices and relying on the marketplace—instead of the bureaucracy—the federal government can get better value and greater variety, at lower cost to the taxpayer. This also will enable the military to get state-of-the-art commercial technology that is critical to developing future weapon systems.

SIMPLIFIED ACQUISITION THRESHOLD. The Act streamlines small purchases by raising the threshold for simplified acquisition procedures from $25,000 to $100,000 and by exempting purchases below this threshold from many burdensome requirements. The increase will make an additional 45,000 procurement actions valued at about $3 billion eligible for simplified treatment. Purchases below $100,000 (and above $2,500) will be reserved for small business.

The Act also gives federal agencies greater flexibility to make so-called "micro-purchases" of $2,500 or less. For example, a federal office manager will be able to buy file folders and paper clips at a local discount store without having to fill out a stack of government purchasing forms. Taxpayers will save $50 on every micro-purchase that is made without going through a procurement office.

PILOT PROGRAMS. The Act enables federal agencies to pilot test acquisition concepts that extend beyond those directly authorized. As part of these pilot programs, DoD will be able to use commercially derived aircraft to support military air lift and tanker requirements; commercial engines in military aircraft; commercial training aircraft as its Joint Primary Aircraft Training System; and off-the-shelf computers in the Fire Support Combined Air Tactical Trainer.

BOX A (cont.)

Federal Acquisition Streamlining Act of 1994

ELECTRONIC COMMERCE. In keeping with a 1993 presidential directive, the Act encourages federal agencies to solicit contracts electronically. (As an incentive, the legislation ties agencies' authority to use simplified procedures for purchases between $50,000 and $100,000 to their ability to conduct procurement electronically.) The federal government is establishing a publicly accessible network that will give anyone with a computer and modem the opportunity to learn about and bid on government contracts, and nearly 250 DoD offices, which account for 80 percent of small defense purchases, plan to be on-line within two years. This approach—in effect, procurement by E-mail—should increase workforce productivity by 50 percent, reduce the lead time for federal purchases, save taxpayers money through increased competition, and improve small businesses' access to government procurement opportunities.

CONSIDERATION OF PAST PERFORMANCE. The Act directs the government to consider contractors' past performance when making a contract award. Although this practice is common sense—every consumer gives repeat business to companies that have performed well in the past and shuns those that haven't—the government has not traditionally followed it. Through this legislation, and through management initiatives that the Administration has already begun, the federal government will at long last consider past performance as a routine part of awarding contracts.

Administrative Reform.

Although legislative change is necessary, there is much that DoD must do administratively to reform procurement. Military-unique product and process specifications prescribe, down to the most minute detail, how military items are to be made and tested. These 31,000 "milspecs" impose large costs on contractors and, ultimately, on DoD—costs that often are not justified.

For example, during Operation Desert Storm, the Army needed a large number of global positioning system (GPS) receivers, to tell soldiers precisely where they were located on the battlefield. However, the milspec receiver cost $34,000, weighed 17 pounds, and would have taken 18 months to procure. By going to the commercial market, the Army was able to buy GPS receivers that weighed three pounds and cost $1,300. (Today, the same commercial receiver sells for about $800.)

Consider also the example of shotgun ammunition. The leading U.S. manufacturer has the most efficient commercial factory line in the world—three automated machines, each producing 240 rounds per minute, with quality control done routinely through statistical process control. The firm also supplies DoD, but military process specification requirements prohibit the use of the same machines for making virtually identical shells. Instead, the firm must follow antiquated procedures that require 12 machines, each manned, producing fewer than 100 rounds per minute in total. The company continues to sell to the military only out of a sense of patriotism.

Because stories such as these are far too common, DoD is moving aggressively to reduce its reliance on milspecs in favor of commercial specifications and standards. On June 29, Defense Secretary William Perry ordered a dramatic revision and simplification of the way the Pentagon buys its goods and key components and military systems. Secretary Perry's directive, based on a nine-month study by a "process action team," calls on the military services "to use performance and commercial specifications and standards in lieu of military specifications and standards, unless no practical alternative exists to meet the user's needs." (See Box B.) The Perry directive "turn[s] the present system upside down."

The Challenge Ahead

Restructuring the defense procurement system will not be easy. It has taken us four decades to build up the barnacles on the procurement ship, and it will take a number of years to scrape them off. One thing is certain: Success is essential to ensuring that t[illegible] military has access to the best and mos[illegible]able technology.

BOX B

Specifications and Standards: A New Way of Doing Business

Remarks by Defense Secretary William Perry, on release of his directive on commercial specifications, June 29, 1994:

More than 100 years ago, Victor Hugo said that more powerful than the threat of mighty armies is an idea whose time has come. Integrating the defense industrial base into the national industrial base is an idea whose time has come....

I have just, this afternoon, signed a directive to civilian and military service leaders that directs them to use performance and commercial standards to guide our purchases in lieu of the lengthy, detailed military-unique specifications which we have come to call ... milspecs.

...When we say we're going to rely on performance standards, we mean that instead of relying on milspecs to tell our contractors how to build something, we're going to tell them what we want it to do and then let them build it to achieve that desired result.

For example, when we order jet engines, we'll tell our contractors how much thrust we want, how much durability we want, and let them decide how to build it. Through the use of commercial technology and off-the-shelf procurement, moving to performance specifications can save us up to $700 million over the next two to four years for microelectronics in the Army's new training helicopter alone....

There will still, of course, be situations where we will need to spell out how we want things built in detail. In those cases we still will not rely on milspecs but rather on industrial specifications—the specifications used in industry. In those situations where there are no acceptable industrial specification, or for some reason they are not effective, then the use of milspecs will be authorized as a last resort, but it will require a special waiver.

In short, what we are doing is turning the present system upside down. Today a program manager is able to buy commercial products but he has to get a waiver to do it. He has to do it on an exception basis. In the future, he will be able to use milspecs but he'll have to do it on an exception basis.

[Milspecs] made sense when the DoD set the standard because none existed and when DoD and the defense industry were the leaders in advanced technology. But in the fields of technology most important to the Defense Department today—semiconductors, computers, software, telecommunications—the technical leadership is in [commercial] industry. If we do not accept their standards, we are not only paying the extra price needed to adapt their equipment and their technology to our requirements, but we're also buying a generation of delay in being able to get the equipment....

We have tried to move to commercial products in the past but with very limited success. This time it is different. The action we're taking today is different. It is a directive which calls for major change, but it is not just a directive from above. It is a clear, well thought out approach to reduce our reliance on milspecs. It addresses the impediments to success which we've faced in the past: the training, adequate funding to manage the transition to the new system, and, most importantly, a clear leadership commitment from myself and the services.

Pillar One: Bolster Leading-Edge Dual-Use R&D

Lower defense budgets and advances in commercial technology mean that DoD will be increasingly reliant on civilian firms to supply state-of-the-art components and products at competitive prices. Thus, a new goal for defense R&D is to ensure that U.S. commercial industry remains at the cutting edge in those technologies that are critical to our military capabilities. This may in turn require DoD to support leading-edge R&D that accelerates the development of emerging commercial technologies that are not currently in the repertory of U.S. firms (or of foreign firms that are absolutely reliable suppliers of U.S. military needs). At the same time, DoD must ensure that the technologies developed by U.S. firms meet defense requirements.

This approach has been remarkably effective in the past, particularly in the decades following World War II, when defense-supported R&D and procurement stimulated some of the most significant technological developments of the twentieth century. DoD funded nearly all of the early R&D in computers, setting the stage for a vibrant commercial industry. Early advances in the semiconductor industry were developed by private industry for the military. And in the aircraft industry, military R&D led to fundamental advances in airframe design and jet propulsion, including the first jet engine. Although the role of defense investment is less central now, DoD can still accelerate and influence the direction of new technologies.

DoD already has taken steps toward rebalancing its R&D portfolio to emphasize dual-use technology. The principal defense-wide agency for supporting research and development is the Advanced Research Projects Agency, or ARPA—formerly DARPA, with the prefix of "Defense." Congress in 1992 restored the agency's pre-1972 name of ARPA, to signify the importance of the agency's traditional role of promoting cutting-edge dual-use technologies, as well as defense-unique technology, to meet defense needs. ARPA is now undertaking an ambitious program of investment in advanced technologies that can meet critical defense needs by exploiting the potential for a commercial market. See Box C for a brief history of ARPA accomplishments.

BOX C

The Advanced Research Projects Agency: 37 Years of Bringing About Fundamental Change

ARPA is the crown jewel in DoD's research establishment, and it is considered by many to be the most successful R&D operation in history. ARPA invented what is now the Internet (originally ARPANET), to provide for robust, survivable communications links in the event of wartime disruptions. It pioneered such breakthroughs as "stealth" technology and "smart" weapons. ARPA funded most of the developments behind artificial intelligence and robotics. And it paved the way for U.S. dominance in commercial computing technology by initiating the research behind everything from supercomputers and timesharing systems to computer graphics and the ubiquitous computer mouse.

President Eisenhower created ARPA in 1958 in the wake of Sputnik. Eisenhower and the Congress recognized the need for a defense organization that could take the "long view" in exploring new, high-risk technologies that promised quantum advancement. ARPA was also charged with breaking down bureaucratic barriers inside the Pentagon by funding research that crossed the boundaries of the individual military services.

With a budget of $2.7 billion and only 210 people (half of them support staff), ARPA is a lean and agile organization by any standard. A recent article in *Washington Technology* described ARPA as "an office that doesn't function like the rest of government."[5]

> The genius of ARPA's organization lies in its simplicity: take about 75 of the world's smartest technologists and give them money to spend on the technologies they consider critical to the national defense.
>
> ARPA...is the quintessential virtual organization. It relies on outside contractors, communicates electronically, and works through fluid, ever-changing partnerships and alliances. And because ARPA has no huge, internal research and laboratory bureaucracy to feed, it can sometimes avoid bitter political battles over staff cuts or facilities. ARPA simply shuts down a [marginal] program and lets its contractors adjust.

The military services are a key part of this "virtual organization." The services are responsible for executing many of ARPA's contracts, which increases the likelihood that they will embrace a new technology and rapidly integrate it into their weapons systems.

With the end of the Cold War and the resulting decline in defense spending, ARPA faces a new challenge: using technology to make weapons systems cheaper. Gary Denman, the director of ARPA, told a recent gathering of industry and government officials in San Francisco that "there has been a very major shift at ARPA. We are not only accountable for the development of new widgets but for the affordability of those widgets." That means more attention to electronic commerce, innovative design and manufacturing processes, simulation technology for testing new weapon system designs, and retrofitting old weapons with new electronic brains.

[5] "ARPA," by Andrew Jenks November 10, 1994

BOX C (cont.)

The Advanced Research Projects Agency: 37 Years of Bringing About Fundamental Change

The new environment also requires greater DoD reliance on commercial—or dual-use—firms, to get access to technologies that are more affordable and often more advanced than what is available in the defense sector. The Bush Administration recognized this need—for example, when it advocated ARPA support for SEMATECH, to restore the strength of U.S. commercial semiconductor manufacturing. The Clinton Administration has expanded ARPA's dual-use budget still more.

Indeed, from the start, ARPA followed a dual-use strategy to meet defense needs. Throughout the 1960s, for example, ARPA unabashedly emphasized advanced computer technology with broad commercial applications, on the grounds that the military would be able to buy improved products at lower prices. Among ARPA's greatest accomplishments was its support for Very Large Scale Integration technologies and for reduced instruction set computer (RISC) architectures, which spawned a new generation of commercial firms, including Sun Microsystems and Silicon Graphics.

Budgetary and political pressures eventually led ARPA to reduce (although never abandon) its visionary support for dual-use technology. Among those pressures was the addition of the word "Defense" to ARPA's name in 1972, at a time when many Americans sought to limit the impact of the Pentagon on society. The name change was part of the unfortunate legacy of the Mansfield amendment to the 1970 Defense Authorization Act, which directed DoD to restrict itself to research with direct defense application. Twenty years later, in 1991, a Carnegie Commission panel led by William Perry and Admiral Bobby R. Inman urged DoD to eliminate the "D" in DARPA and return the agency to its traditional emphasis on dual-use, as well as defense-unique, technology to meet defense needs.

With or without the "D" in its name, ARPA has always had a clear mission focused on military needs, avoidance of technological surprise, and a drive toward innovation and fundamental change. Although the challenges ARPA has faced over nearly four decades have changed, the objective has not: ARPA continues to look for ways to leverage the best technology for our fighting men and women. The proven ability of this remarkable agency to deliver leading-edge technology is crucial to meeting our long-term military objectives and to ensuring that we never have a "technologically hollow force."

The Technology Reinvestment Project, a multi-agency effort managed by ARPA, is DoD's largest and most visible dual-use program. The TRP awards matching funds to industry-led projects, selected purely on the basis of merit, to develop new dual-use technologies that meet defense needs. For example, one TRP consortium is blazing the trail in **multi-chip module (MCM) technology**. By replacing separate components with a single module, MCMs allow electronic systems to achieve faster performance, greater reliability, lower power consumption, and lower production costs. The military needs MCMs for activities ranging from precision guidance of advanced weaponry to real-time signal processing for intelligence applications. On the commercial side, MCMs open the door to a vast range of new and improved products including global positioning systems, real-time engine controllers for automobiles, and digital signal processors for speech and images in telecommunications. Use of MCMs in the scalable computers described below should enable U.S. computer companies to advance computer performance by a generation. Similarly, a high-performance dual-use manufacturing base for multichip modules can provide the foundation for U.S. military and commercial leadership in information technology well into the twenty-first century.

TRP projects are directed at meeting military needs in a range of areas:

- **Low-cost night vision:** U.S. troops will be able to "own the night," through widespread use of infrared sensors made 10 times cheaper by leveraging new commercial technology.
- **High-density data storage:** Vast increases in portable, low-cost data storage will give our front-line soldiers immediate access to the best information and intelligence.
- **Battlefield casualty treatment:** New sensors and information systems will greatly improve the ability to find, diagnose and treat injured combatants during the critical first hour they are down in the field.
- **Affordable composite aircraft structures:** Lightweight, polymer composites for aircraft engines will increase the performance and range of military aircraft while lowering the cost of repair and maintenance.
- **Detection of chemical and biological agents:** Sensors to detect and identify chemical and biological agents in the battlefield will protect U.S. troops from this growing threat.

(See the appendix for more detail on the TRP.)

In other dual-use initiatives, ARPA is targeting investments in focused "thrust areas"—computing and software, simulation, electronics, sensors, and manufacturing—to ensure that commercial firms in this country can supply the superior technologies that will maintain our military advantage. One initiative aims to perform massive computing tasks—that are done today on single, central supercomputers—on multiple computers scaled for personal use. Over the next five years, **scalable computer architectures** (together with MCM technology) will make extremely powerful software applications available to a broad range of civilian as well as military users, giving them the analytical capability to solve highly complex problems.

Scalable computers are revolutionizing information processing. They will dramatically enhance the ability of battle-site command and control centers to process tactical information and position (or reposition) weapons systems. Similarly, because of their mobility, scalable computers will give surface ships the computing power to mount tactical missile defense, and airborne command and control centers such as JSTARS will be able to identify and track multiple targets in high-clutter environments.

Another ARPA initiative involves **an all-optical network testbed** that will lay the foundation for an information superhighway by interconnecting computers throughout the country. All-optical networks are necessary for the military to take full advantage of the speed of scalable computers. The ability to transfer high resolution images, full motion video, and massive amounts of data in real time also will stimulate new applications in medicine, education and business, making the technology more affordable to the military.

Distributed simulation is another dual-use technology with potentially high payoffs to the military. Now used extensively to train warfighters to operate their equipment under battlefield conditions, distributed simulation can also augment testing and evaluation of weapon systems and improve their manufacture.

A special application of advanced computer simulation integrates live training with actual operations. In military applications, simulation displayed on a computer screen interacts with information coming in from the operations of real vehicles and weapons. The power of this technology was demonstrated in the recently completed Synthetic Theater of War-Europe exercise, when over 2,700 combat entities (ranging from individual soldiers to tank and aircraft crews) on two continents participated in a major drill that linked simulations with live maneuvers. This virtual reality training develops skills quickly and inexpensively, and offers an alternative to costly field maneuvers.

In addition to ARPA, each of the military services is pursuing focused dual-use R&D to leverage commercial technology. For example, the Air Force leads the **Integrated High Performance Turbine Engine Technology Program**

(IHPTET), which aims to double the capability of the propulsion system for military aircraft and cruise missiles. Six of the seven manufacturers participating in IHPTET are active in both commercial and military aerospace markets. This facilitates the migration of technologies developed for the military into commercial products, and vice versa, and ensures that there is sufficient production capability to support future military needs.

The Army has a comparable effort to develop **rotorcraft technologies**. As military demand for helicopters declines, commercial sales are increasingly important in sustaining a robust and dynamic technology base. The Army is teaming with industry on a cost-shared basis to develop dual-use design, engineering and manufacturing technologies for rotorcraft. This effort is modeled after an Army partnership with the Big Three automobile manufacturers and their suppliers to develop dual-use technology for land-based vehicles.

DoD's new emphasis on dual-use requires the agency to learn to work more closely both with commercial industry and with the federal government's civilian research agencies to support the technological underpinnings of sectors critical to national security. DoD is actively consulting with industry to set its dual-use priorities. To encourage participation by firms that are not traditional defense contractors, ARPA is making broad use of its "cooperative agreements and other transactions" authority, which is exempt from the federal acquisition regulations and limits the government's claim on patents and technical data. In February 1994, this authority was delegated to the military services as well. Since commercialization is the goal of these dual-use partnerships, the government ultimately will get the fruits of technology development in the form of products rather than data rights.

Pillar Two: Integrate Commercial and Military Production to Enable Industry to "Dual Produce"

In addition to exploiting the potential of advanced commercial technologies to meet defense needs, the Defense Department is making investments to help integrate defense and commercial production. DoD is pursuing this strategy—to enable industry to "dual produce"—in two quite different ways. First, it is supporting efforts to transition existing defense technologies to commercial applications, in order to make those technologies more affordable and accessible to the military. Second, DoD is helping U.S. manufacturing firms become more flexible, to enable low-volume production of defense products at commercial prices.

"Spinoff" of Defense Technology.

Although the defense technology base is large and highly advanced, the bulk of defense R&D never leaves the defense sector. When defense technology is used to build commercial capabilities, the benefits are substantial: The economies of scale and scope generated by commercial production mean DoD's costs are lower and the technology is more likely to remain accessible for defense use. Commercialization—particularly if carried out by a civilian firm—often involves additional cost-saving innovation, which in turn can improve the defense system. Finally, the creation of new civilian markets strengthens our overall industrial base.

To illustrate, a few years ago, DoD pursued **microwave monolithic integrated circuit (MIMIC) technology** as a strictly military development, but the high costs prohibited widespread defense use of the devices. MIMICs are advanced gallium arsenide semiconductors used for military radar. As part of the MIMIC program, DoD now encourages contractors to pursue commercial applications—in collision avoidance systems for automobiles, satellite communications, and air traffic control signal processing. The payoff to defense is the world's best radar at a lower cost by leveraging commercial production—one of many dual-use success stories. (See Box D.)

BOX D

A Dual-Use Technology for Fighter Aircraft and School Buses

Betty Hougland believes that FOREWARN*, the civilian sibling of a military technology, saved the life of a little boy who got off the school bus she was driving, and then disappeared from view.

Ms. Hougland, a ten-year veteran driver in Kokomo, Indiana, had stopped her bus at a busy stop where 16 children got off. She watched the chattering crowd move away, checked the mirrors that see into blind spots around the bus, and was ready to roll. Then the FOREWARN'S buzzer went off and red lights flashed on its screen, indicating that something was right in front of the bus, too close and too low to see. It turned out to be "a little guy, a kindergartner," said Ms. Hougland. He had dropped his backpack and spilled its contents, and had dived almost underneath the bus to pick them up.

The FOREWARN system makes use of MIMIC (microwave monolithic integrated circuit), a semiconductor device built on gallium arsenide instead of the more familiar silicon, developed for military radar and communications by the Defense Department's Advanced Research Projects Agency (ARPA). For its advanced tactical fighter, the F-22, the Air Force chose a sophisticated phased-array radar based on MIMIC. There are 2,000 transmit-receive modules in a phased-array radar set, and every module originally cost $8,000. That added up to a $16 million price tag for the radar on every F-22.

The Air Force and ARPA worked with their contractors to reduce the price, brought it down below $2,000, and expect it to drop further to a few hundred dollars—assuming that production of the military device can be combined with high-volume production of a commercial version. A very large potential market could be automobiles, which might use the system for such things as safe following or cruise control. The Air Force could benefit greatly if a large commercial market materialized, since it could then have low-volume access to a high-volume line. However, the price is still high for the auto market.

One of the Air Force contractors is Hughes Aircraft, a subsidiary of GM Hughes Electronics. Delco Electronics, another subsidiary of GM Hughes Electronics, saw an important immediate market for a civilian version of the device. Every year, there are twenty-odd serious accidents and eight fatalities, on average, when children are run over by their own school buses. Obviously, it is worth a lot to avoid these accidents.

Delco's know-how in marketing and commercial production, combined with the MIMIC-radar technology that Hughes brought to the table, produced a system suitable for school buses. The system includes two radar modules and a display, and can be sold at a fleet price of $1,895. A Delco spokesman said the company is ramping up, and can soon produce enough FOREWARN systems to equip every school bus in the country, whenever school boards are ready to buy.

*FOREWARN is a trademark of the Delco Electronics Corporation

BOX D (cont.)

A Dual-Use Technology for Fighter Aircraft and School Buses

A special joint venture between Hughes and Delco, HE Microwave, produces both the school bus module and a fighter aircraft version on the same production line, with a changeover time of less than two hours. By using readily available commercial process technology and designing for manufacturability and easy testing, HE Microwave gained further cuts in the cost of both the civilian and military versions—with no sacrifice in quality and reliability. High-volume production of a module for automobiles could bring economies of scale that would push costs down still further. HE Microwave is aiming for a production system that can make modules of various dimensions and performance characteristics with no time out for switching.

The cumbersome Department of Defense rules for procurement have not applied so far in this case, because the military purchases have been for demonstration purposes, not procurement. Reforms urged by the Clinton Administration and recently adopted by the Congress change federal procurement laws so as to give DoD much more flexibility in buying commercial products. In future purchases, the Air Force will be able to take full advantage of the commercial-military integration that is already reality on the production line.

As for Ms. Hougland, who has had FOREWARN on her bus for a year and a half, "I'm lost when I have to drive a spare bus without it." She says that driving a school bus can take all your attention, and more. "It's an extra set of eyes and ears for me. I love it."

Many of the projects supported by the Technology Reinvestment Project are designed to adapt military technology for the commercial market, in line with Pillar 2. These projects share two common traits. First, participants must contribute at least half the cost of a project, to ensure that project activities are driven by market needs. Second, like the Hughes-Delco joint venture to produce FOREWARN, most TRP projects bring defense and commercial firms together in a single team. This partnering approach provides a practical way—more feasible than efforts by defense firms to "convert"—of moving defense technology and talent into the commercial market.

The TRP's **Precision Laser Machining Project** is an example. DoD-funded diode-pumped laser technology has considerable potential for improving the manufacturing process for automobiles, aircraft, engines and ships, by enabling higher precision and greater tooling speeds than are currently available. No less important, adaptation of lasers for industrial use will yield an affordable technique with which helicopters and aircraft can track and jam heatseeking missiles. The TRP project team includes the firms that supply and use laser technology for military purposes, but it also includes the non-defense suppliers and users that want to adapt this technology for commercial application. This vertically and horizontally integrated structure ensures that the products being developed by the consortium will reflect user needs. (See Box E.)

BOX E

TRP'S Precision Laser Machining Project

The TRP's Precision Laser Machining (PLM) Project represents a dual-use triple play. First, the PLM consortium brings together defense and commercial firms to put the speed and precision of military laser technology to work in machine shops and manufacturing plants across the U.S. In addition to strengthening U.S. manufacturing capabilities in a range of industries, the PLM lasers will improve American competitiveness in the laser machine tool business itself. Development of precision laser machine tools will in turn provide direct benefits to DoD; that's play number two. Experts estimate, for example, that over time the new laser machining techniques can increase aircraft fuel savings by several percent, by improving the uniformity of millions of microscopic holes drilled in airframes to reduce wind drag. Last but not least, the PLM project will "spin back" to DoD a superior method for defeating enemy missiles.

Lasers are highly focused beams of light that can deliver a large amount of energy quickly to a tiny, often inaccessible area with little or no damage to surrounding areas. They have proven effective in manufacturing applications such as high-speed welding of sheet metal for ships and automobiles, drilling of cooling channels in aircraft engines, and precision cutting of composites for lightweight airframes. However, most laser machine tools today use either carbon dioxide gas lasers or lamp-pumped solid state lasers, both of which have major limitations.

The PLM consortium will develop a new class of high-speed, high-precision laser machine tools using diode-array-pumped solid state lasers. Developed by DoD because of its greater precision and reliability for battlefield applications, this diode-pumped laser technology will be able to deliver:

- Brighter, higher quality laser beams that can target a work surface "spot" about one-tenth the size, with an energy density 100 times greater than current lasers;
- Higher peak power (25 megawatts versus the current 50 kilowatts) and higher average power (6 kilowatts versus the current 3 kilowatts for lamp-pumped solid state lasers);
- Smaller packaging (10-20 cubic feet versus 70 and 150 cubic feet for available lasers);
- Lower maintenance requirements (maintenance intervals of 10,000-20,000 hours versus the current 500-1000 hours).

For a broad range of defense and commercial products, these new lasers will be able to cut and drill holes faster, deeper, and more accurately; cut and shape a wider variety of composite materials; weld aluminum and other materials that dissipate heat quickly; and reduce the size of the heat-affected zone, allowing new and higher precision applications. For example,

- More precise drilling of cooling channels in aircraft engine turbine blades constructed of super alloys will allow the engines to operate 20 degrees cooler. This will double the life of military engines.

BOX E (cont.)

TRP'S Precision Laser Machining Project

- PLM lasers, delivered through fiber optics, will make it possible to weld very large structures—for example, they will enable deep penetration welding of double-hulled panels for military and commercial ships.
- Use of next-generation lasers to weld automobile bodies will mean a savings of $185 per auto in materials and time; it will also reduce the weight of each auto by 45 pounds, which will increase fuel efficiency.

The 19-member PLM consortium, led by TRW, has both defense and commercial firms, including the technology developers (Fibertek, Hughes, Northrop, SDL and TRW); the tool integrators (Process Equipment Co. and Utilase Systems); end users of laser tools (Boeing, Caterpillar, Chrysler, Cummins Engine, Ford, G.E. Aircraft Engines, General Motors, Newport News Shipbuilding, TRW and United Technologies); and process developers (Edison Welding Institute, University of Illinois, and Pennsylvania State University). This vertically and horizontally integrated structure means that the products being developed will be fully responsive to user needs. The involvement of "tool integrators"—two small firms that specialize in building laser capabilities into machine tools—ensures that the products will be factory-compatible. The consortium plans to have its new laser tools ready for commercial use by 1996. According to L.N. Durvasula, the ARPA program manager who is overseeing the PLM project, the tools will be cost competitive with existing industrial lasers.

But there's more to the story. Commercialization of diode-pumped lasers will make them more affordable to DoD for their original, battlefield applications, such as precision-guided munitions and remote detection of chemical and biological agents. Most important, the work of the PLM consortium will yield an affordable solution to a problem that has vexed DoD: how to track and defeat missiles targeted at helicopters and aircraft providing close air support. These low-flying craft are extremely vulnerable because an enemy soldier can pop out from behind a tree and "shoulder launch" a powerful heatseeking missile. The current countermeasure—flares and flashlamps—are bulky and not always effective; lasers don't work because the atmosphere distorts the beam, causing it to miss the target. The PLM project faces a similar problem with lasers on the factory floor, and the consortium's solution—"phase conjugation"—will also serve the military's purposes. The key is affordability. Although DoD is pursuing other, defense-unique ways to correct atmospheric distortion of laser beams, they are extremely expensive. "We need to bring the cost down below $100,000," says ARPA's Durvasula, for the system to be cost-effective on a $10 million helicopter.

Federal laboratories, as major sources of advanced technology, will play an important role under Pillar 2. The Department of Defense (like the Department of Energy) is taking additional steps to institutionalize a dual-use approach in its laboratories and to interest industry in lab technologies that have commercial potential. Most important, DoD has made it easier for industry to work with the labs. For example, the DoD labs were given the authority to use "cooperative agreements", which allow for greater flexibility in the partnership arrangements that can be negotiated with industry. In addition, DoD will make technology transfer and dual-use partnerships with industry part of the explicit mission of each laboratory.

Flexible Manufacturing and Enterprise Integration.

To better integrate defense and commercial production, DoD also is investing in technologies and activities with the goal of enabling firms to manufacture items in small volumes just about as economically as in large scale production. This flexibility will allow the custom products that the military needs to be produced alongside commercial versions of the same product.

The broader goal is to have a robust industrial base capable of meeting future military needs with products that achieve "world-class" benchmarks for cost, quality and cycle time. For many military products, this goal requires a 30 to 50 percent reduction in current development and production costs, a comparable reduction in cycle time, near-perfect quality, and built-in life-cycle support for the product.

Advanced manufacturing technology is central to this effort, and DoD is investing in a number of areas that are critical to bringing about these dramatic advances:

- rapid prototyping
- software tools to reduce machine set-up times and tool inventories
- factory simulation tools and automated process planning
- information services that facilitate distributed manufacturing and electronic commerce
- interfaces that facilitate data exchange among different systems
- highly flexible and affordable machine tools and processing equipment

Fully a quarter of ARPA's $2.7 billion budget is devoted to advanced manufacturing technology. The Services are investing in dual-use manufacturing as well—primarily through the Defense Manufacturing Science and Technology (formerly MANTECH) Program. **The Air Force Manufacturing Science and Technology Program**, for example, is demonstrating the ability to produce sophisticated circuit boards for the F-22 aircraft on a high-volume production line, located in a commercial division of TRW, that also manufactures circuit boards for trucks. (Among other challenges, the Air Force has had to work around its traditional contracting procedures, which would disrupt TRW's ongoing commercial business.) The goal is to show that commercial manufacturing practices, coupled with factory flexibility, can meet military needs for functionality and durability at a cost savings to DoD of 30 to 50 percent.

Another example of the new emphasis on flexible manufacturing is ARPA's **Affordable Multi-Missile Manufacturing Program**, which is asking contractors to propose ways to produce a family of missiles or components on the same assembly line. DoD funding to buy tactical missiles has gone from $9 billion in 1989 to $3 billion today, and several companies have dropped out of the missile business. ARPA's flexible manufacturing strategy will lower the unit cost of missiles and help DoD ensure that industry survivors can supply a wide range of missiles. The program goal is to cut the cost of missiles now in production by 25 percent and to demonstrate that missiles not yet in production can be manufactured for half the cost previously estimated.

The greatest benefits will come from combining manufacturing technology with organizational and managerial changes. ARPA's **Agile Manufacturing Program**, implemented jointly with the National Science Foundation (NSF), takes this broader perspective. "Agile" is the term coined by an industry-led group that in 1991 published its vision for twenty-first century manufacturing. The DoD-sponsored group forecast an environment in which competitive advantage belongs to manufacturing firms that are able to thrive in an environment of continuous, unanticipated change. A key concept in the vision of agile manufacturing is the "virtual enterprise"—a group of vertically and/or horizontally integrated companies that come together via computer network to pursue a specific market opportunity.

The Agile Manufacturing Program was launched as a joint ARPA-NSF initiative in 1993. The program originally included three elements: (1) an industry forum to continue developing the concepts, best practices and benchmarks of agile manufacturing; (2) university-industry research institutes in key industrial sectors—initially, electronics, aerospace and machine tools; and (3) an "enterprise integration" network to test actual applications of agile manufacturing. In 1994, the program was expanded to include demonstrations and pilot programs to test agile business practices and enabling technologies.

Another initiative, the **Dual-Use Technology Application Program** (DUTAP) is funding manufacturing testbeds and other production infrastructure to support DoD's dual-use R&D. For example, the testbed component of the National Flat Panel Display Initiative (described below) is a DUTAP project. Located in four different facilities, this testbed is helping U.S. firms overcome the technical obstacles to establishing a dual-use display manufacturing capability. Specifically, the testbed will be used to develop and evaluate manufacturing processes for thin film transistor substrates, cell assembly and liquid crystal filling processes, and display packaging and assembly operations.

Pillar Three: Insert Commercial Products and Capabilities into Defense Systems

If the military is to realize the benefits of dual-use R&D and integrated production, it must incorporate commercial products, processes and technologies into defense systems wherever possible. Initiatives that encourage "insertion" of commercial technologies and products into the development, production and support of military systems make up the third pillar of the dual-use technology plan.

The insertion pillar recognizes that acquisition reform—which eliminates the regulatory barriers to buying commercial—is not sufficient. Programs managers and contractors still face up-front costs and risks to adopting commercial products and technologies—for example, the cost of certifying that a commercial integrated circuit will withstand the necessary temperature extremes, or the cost of engineering a commercial component to fit into an existing military system. Thus, DoD must try to offset those costs and risks, and it must do so at a level in the organization above that of the individual weapon program, so that common costs are shared rather than duplicated.

Because commercial off-the-shelf materials and products are not always adaptable to existing weapon systems, successful insertion requires that military systems be "designed for dual use"—that is, designed from the outset to incorporate commercial rather than defense-unique materials, technologies and components. Cost and manufacturability would become key considerations in the design process, which would emphasize commonality and standardization of parts, modularity, adaptability, open architecture, and the use of fewer parts.[7] Designing for dual-use production processes can also allow a defense-unique item to be manufactured or maintained in a commercial facility.

To encourage commercial insertion and design for dual use, the Defense Department is proceeding on several fronts. First, DoD is providing individual military program offices with the technical knowledge to identify and assess opportunities for insertion in the weapon systems they manage. For example, industry contractors are working with DoD program staff to develop a process for inserting non-military parts in the Single Channel Ground and Airborne Radio System (SINCGARS). The broader goal is to develop a corps of "smart buyers" in the military with a detailed knowledge of relevant commercial technologies and an understanding of commercial markets and buying practices.

[7]For most weapon systems, the cost of ownership—operation, maintenance, evolutionary upgrade, and demilitarization—exceeds the acquisition cost. Because 80 percent of this life-cycle cost is determined during the very early concept and preliminary design phases, affordability must be a key design objective.

Second, DoD is promoting department-wide opportunities to insert commercial technology, with investments being made jointly by the military services. For example, the Pentagon is working with an industry task force to assess and document the range of environments in which commercial integrated circuits (ICs)—which typically are packaged in plastic, rather than the high-cost ceramic used for most milspec chips—can be substituted in defense systems. Commercial ICs are being used now in many military systems, and anecdotal information suggests that they cost only a fraction as much as their milspec counterparts, with no loss in performance.

Finally, the Pentagon is asking the services to actively develop plans and programs to insert commercial capabilities as part of ongoing weapon system development and upgrade activities. Each service will select at least three acquisition programs to be used as pilot projects for integration of military and commercial production (Pillar 2) and commercial insertion (Pillar 3). Among other things, program managers are expected to justify the tradeoffs they make between performance and cost.

One example of this approach is the ARPA-led **Tier II+ High Altitude Endurance Unmanned Aerial Vehicle (UAV) Program**. The UAV is designed to carry out high-altitude surveillance and reconnaissance in enemy territory even during bad weather. The goal is to provide military commanders with real-time information on the opponent's terrain and infrastructure, and on the position and concentration of enemy troops.

When DoD solicited proposals to develop the UAV, contractors were given only one absolute requirement: it must cost no more than $10 million. DoD specified *what* it wanted the UAV to be capable of doing—subject to the cost constraint—but it left it up to contractors to determine *how* to accomplish that. To give them the necessary flexibility, ARPA used a streamlined acquisition process.

This flexibility, combined with DoD's cost ceiling and an ambitious deadline for prototype delivery, meant that contractors proposed designs that relied heavily on existing commercial technology. Most defense contractors formed partnerships with commercial companies—e.g., a manufacturer of business jet airframes. A total of 14 teams submitted proposals—a sign of industry's enthusiasm for this innovative program.

Flat Panel Displays: A Comprehensive Dual-Use Initiative

To foster U.S. manufacturing capability in flat panel displays, a technology with increasingly important military applications, DoD last year announced a new interagency program that incorporates all three pillars of its dual-use strategy. The National Flat Panel Display Initiative continues the successful R&D effort in that technology now run by ARPA. It adds a second manufacturing testbed—a facility designed to develop the knowledge base for high-volume production. The initiative also adds a targeted category of R&D for firms that demonstrate a commitment to high-volume manufacturing of displays. Finally, DoD will actively encourage insertion of domestically produced flat panel displays in military systems.

A U.S. manufacturing capability in flat panel displays is important because DoD needs early and assured access to displays that are both leading-edge and affordable; production is now heavily concentrated in Japan, with one company controlling over half of the market. The Administration's R&D incentive program is designed to encourage high-volume production of flat panel displays in the U.S., in order to meet military needs. The program is run as a competition based on technical merit, defense relevance and contribution toward a self-sustaining industry, regardless of the specific technology employed. (See Box F.)

BOX F

National Flat Panel Display Initiative

Success on the battlefield of the future will hinge on the ability to collect, collate, analyze and disseminate a torrent of information. Flat panel displays, now seen chiefly in laptop computers, will be the primary means by which the combatant will dip from this river of data.

Current simulations of the F-15 cockpit, for example, suggest that merely having access to a large tactical situation display (which can be implemented only as a flat panel display) would raise our pilots' "kill ratios" by about 30 percent.

Revolutionary future applications will include on-demand presentation of high-resolution imagery and mapping data to individual soldiers in the field; this information will be as important to American soldiers in future conflicts as two-way radios and GPS receivers were in Desert Storm. In headquarters, flat panel displays will give commanders the ability to call on intelligence data bases distributed around the globe instantly; and it will offer the potential to sketch position, observations, and proposed actions on a map display and communicate with widely dispersed units to mount coordinated actions.

To capitalize on this potential, the military needs early access to the latest generation display technologies, and needs it while these technologies are still in development in order to work out the battlefield and air combat tactics and strategies for their use. We need responsive suppliers who will customize commercially derived technology to produce displays that operate in both desert and Arctic temperatures, are readable in sunlight as well as night combat, offer extremely high resolutions, integrate specialized information processing capabilities, and are available in nonstandard sizes. And it all must be affordable.

But there's a problem. Currently, a handful of foreign firms dominate the flat panel display industry, with over 90 percent of global production. The world's dominant flat panel display manufacturer, the Sharp Corporation of Japan, has not shown a willingness to work with DoD on its specialized requirements. With other producers, it's speculative at best.

Moreover, U.S. firms today show little potential for meeting critical DoD requirements if left undisturbed.

In the past, when military demand drove innovation, DoD would have worked with a small group of defense-oriented companies, invested in defense-unique R&D and production facilities, and ended up with a group of captive suppliers dependent on defense business. But that approach will no longer work. DoD demand will never exceed 5 percent of the U.S. market for flat panel displays. Mushrooming commercial demand will drive the display industry. To benefit from economies of scale and keep up with leading-edge technologies, DoD must piggyback on commercial production.

To help develop suppliers that are competitive in commercial markets and willing to provide the necessary early, assured and affordable access, the Clinton Administration last year announced a National Flat Panel Display Initiative.

BOX F (cont.)

National Flat Panel Display Initiative

Under this DoD-led initiative, the Pentagon is, first, continuing with its very successful core research program in display technologies and infrastructure. As a result of this program, U.S. electronics firms have developed some of the world's best display technology. As the major piece of this program, ARPA will provide about $70 million per year for R&D on leading-edge, dual-use product and process technology in flat panel displays—much of it focused on equipment and materials suppliers.

Second, DoD is increasing its emphasis on exploring manufacturing processes, which are a major stumbling block to the to the development of a domestic display industry. ARPA funded a second manufacturing testbed that will explore high-volume production processes and that will share the resulting know-how with virtually every element of the U.S. display industry.

Third, DoD is making innovative new use of R&D matching funds to help jumpstart a domestic manufacturing capability: An additional allotment of defense funds for research on future display technologies is available only to companies that commit to domestic volume production for current generation products, and that are willing to support DoD display requirements.

Finally, to encourage "insertion," DoD is encouraging program managers to replace cathode ray tubes in their weapon systems with domestically produced flat panel displays. Program managers are allowed one or more extra, "free" flat panel displays for every one they purchase; funds for the extra displays come from another DoD source, not from the program manager's budget. Additional funds are available to help program managers qualify these displays for use in their weapon systems.

This initiative does not subsidize production or attempt to "pick winners." Instead, it is technology-neutral and company-neutral. It does not attempt to substitute a government bureaucrat's judgment for the judgment of the market. It does attempt to tip the balance in favor of production by supporting next-generation R&D by those already contemplating production. The idea is for the Defense Department to join in developing technology for the year 2000 with those likely to be in a position to actually build products for DoD in 2000.

Critics of this program observe that "it's hard for government to improve consistently on the market." This observation is both correct and beside the point. Where market forces are at work, DoD is taking steps to support the choices of the market as to technology and production. Where there is no competitive market, DoD is acting to solve national security problems.

Perhaps these critics would be less concerned if they thought of this initiative as an insurance policy. If they're right, DoD will cancel the initiative before the premiums get too high. But if they're wrong, their prescription of doing nothing would be a disaster.

Criteria for Making Dual-Use Technology Investments

Although the Administration has significantly increased the funding for dual-use technology, the Defense Department nevertheless must make difficult choices about how to invest its R&D dollars. DoD is continuing its strong support for basic research in areas that have the potential to spawn critical dual-use technologies. Other dual-use technology investments will be made based on three broad criteria:

- **Importance to Defense Mission**: Which technological opportunities will contribute the most to national security?
- **Need for Government Action**: Does this investment meet the "but for" test—that is, but for federal funding, industry would not undertake the investment on its own?
- **Opportunity for Leverage**: Will this investment lead to a viable commercial industry that is also capable of meeting defense needs? Key considerations include:
  - Probability of technical success
  - Potential for a pervasive technological impact
  - Commercial potential of the technology
  - Industry willingness to cost-share
  - Industry's readiness to make use of the technology
  - Scope of defense activities affected
  - Potential savings to the military

The importance of a technology's commercial potential means that firms will have to address that issue explicitly in their proposals (although the willingness of industry to contribute a significant share of project costs will remain the most convincing test of commercial potential). The Department of Defense may have to expand its process for evaluating proposed technology projects to include reviewers with business experience.

Finally, dual-use technology projects must include clear objectives—or "deliverables"—by which to measure ongoing progress. Periodic assessment will be built into the program, with "exit ramps" to allow for funding termination if objectives are not being met.

International Considerations

DoD's dual-use initiatives are open to participation by our foreign friends and allies, subject to national security considerations and a "national benefit" test to ensure that the foreign participant makes a significant contribution to program objectives. Moreover, just as American firms look to international alliances to provide access to foreign technology, so too must the military seek greater access to state-of-the-art commercial technology that exists outside of the U.S.

More broadly, as the Defense Department makes greater use of commercial technology, it finds itself more tightly knit than ever before in the growing web of international supply chains and alliances that characterize today's global economy. DoD's dual-use strategy is careful to reflect other government policy objectives, such as export controls, international protection of intellectual property, and the need to avoid transferring technology to foreign countries when that would harm U.S. industry. In particular, dual-use initiatives will adhere to U.S. obligations under the General Agreement on Tariffs and Trade and the World Trade Organization, in keeping with the leading U.S. role in supporting an open international trading system and the benefits of such a system for our economic security.

Conclusion

Since World War II, U.S. military superiority has been based on our technological advantage, and technology will be even more important in the unpredictable security environment we now face. For technology to be an effective bulwark, however, we must abandon our reliance on a separate and increasingly isolated defense industrial base. We must recognize that commercial industry, not the military, is the driving force behind many advanced technologies today.

The Defense Department's new dual-use technology strategy, building on the foundation of ongoing defense acquisition reform, is designed to eliminate the artificial barriers built up over the years between commercial and defense industry. This will save billions of dollars annually in procurement costs and broaden the industrial base upon which defense can draw. Most important, it will give

DoD access to advanced technologies in the commercial sector that are critical to developing future weapon systems. This dual-use strategy, coupled with continued reliance on the superior systems design and integration skills of U.S. contractors, should ensure a superior fighting force for decades to come.

Among other actions, the military has turned to ARPA to help find a path through this new dual-use environment. ARPA has a 37-year tradition of investment in dual-use technology to meet defense needs, leading to the development of the Internet, supercomputers and artificial intelligence. Through programs such as the Technology Reinvestment Project, ARPA—working closely with the services—is leveraging the advanced technologies and efficient production capabilities of commercial industry to keep our military the strongest in the world.

Integration of the commercial and defense industrial bases is a powerful idea whose time has come, as Defense Secretary Perry said when he turned DoD's milspec system upside down. An integrated base is clearly essential to continued military strength. Commercial-military integration also contributes to U.S. industrial performance and a stronger economy overall. No other strategy is more important to ensuring continued U.S. international superiority in a post-Cold War world.

Appendix

Technology Reinvestment Project

Technology, the key to America's Cold War military strategy, will be even more important in the unpredictable security environment we now face. But the military must reduce its reliance on a "defense-unique" technology and industrial base in response to two new realities:

- Cold War defense budgets are no longer sustainable; affordability, along with performance, must now be a primary concern for DoD.
- Many of the technologies most critical to defense are emerging in the commercial sector; currently, defense access to these technologies is limited.

DoD's dual-use technology strategy is a response to these new realities, and the Technology Reinvestment Project (TRP) is DoD's largest dual-use technology program.

The mission of the TRP *is to give the Department of Defense greater access to affordable, leading-edge technology by leveraging commercial know-how, investments and markets for military benefit.* This mission is embodied in two strategic goals: (1) to enhance the technological superiority of defense systems while lowering costs; and (2) to strengthen the industrial base on which DoD depends while lowering its cost.

To achieve these goals, the TRP awards funds, on a cost-shared basis, to industry-led projects to create new dual-use technologies. These **technology development** projects are of two types, corresponding to the first two pillars of DoD's dual-use technology strategy.

- **Leveraging commercial technology**: The first type of project advances the commercial development of key technologies that meet defense needs. Because commercial demand will eventually make these technologies more affordable to the military, DoD benefits by accelerating the development of the technology while simultaneously ensuring that it meets defense requirements.
- **Transitioning defense technology**: The second type of project promotes the transitioning of defense technologies to commercial applications. The creation or enhancement of commercial markets for these technologies makes them more affordable and accessible to the military.

Although the lion's share of funds has gone to technology development, the TRP has awarded smaller amounts of money to projects in two other areas: **technology deployment**, to build a *"dual-produce" capability* in the U.S. manufacturing base, by helping small defense firms compete in commercial markets; and **manufacturing engineering education**, to reorient engineering education to the dual-use manufacturing industries of the future. Last year, the Department of Commerce assumed full responsibility for supporting technology deployment.

Winning projects are chosen solely on the basis of merit by technical evaluators from the Department of Defense and other federal agencies. To ensure that TRP projects are driven by market needs, participants must contribute at least half the cost of the project.

The TRP is implemented by the Department of Defense (ARPA and the military services), working jointly with five other agencies: the Departments of Commerce, Energy and Transportation, the National Science Foundation and the National Aeronautics and Space Administration. The FY93 budget for the TRP was $472 million; in FY94 the program received $404 million. The FY95 appropriation is $443 million. The President's FY96 Budget requests $500 million for the TRP.

President Clinton unveiled the TRP on March 11, 1993. The subsequent competition was heavily oversubscribed: the TRP received 2,850 proposals, requesting $8.5 billion.[8] These proposals were evaluated by 300 experts from DoD and other federal agencies. Between October 1993 and February 1994, the TRP announced awards of matching federal funds totaling $605 million to 212 projects, involving 1,600 firms, universities and other participants. Awards went to *all* of the 1993 proposals that were "highly recommended".

In March 1994, the TRP announced 1993 Small Business Innovation Research (SBIR) awards of $15 million to 153 small businesses.

A second TRP competition got underway in April 1994. In October, the TRP awarded $200 million in federal matching funds, bringing to $820 million the total size of awards announced so far under the TRP. The awards went to 39 projects involving 224 participants.

A third TRP competition, to allocate $415 million, was announced on October 21, 1994. DoD will announce the awards in mid-1995.

Assessing the TRP: Insights from the First Two Years

Few federal programs have been as enthusiastically received and as carefully scrutinized as the TRP. The program has received considerable praise as well as its share of criticism—much of that the result of a misunderstanding of its mission (see Box G). In response to suggestions from industry, ARPA has modified the program to increase applicants' success rate and expand participation by small business. In addition, the TRP has increased the military services' involvement in the program, to ensure that TRP-developed technologies are rapidly integrated into defense weapon systems.

[8]Industry responded aggressively to the TRP solicitation despite its complexity (eight statutory programs, each with its own requirements); the $8.5 billion in requested funds exceeded available funds by a factor of 17 overall, and by as much as 30 or 40 for some of the technology development programs. Moreover, many of the proposals were very good: Although the TRP funded all of the "highly recommended" proposals—about 7 percent—the program was unable to fund any of a large number of proposals that were "recommended" by evaluators.

BOX G

TRP Mission: Dual Use Not "Defense Conversion"

Although the Technology Reinvestment Project has completed two competition cycles and awarded more than $800 million in matching funds, its basic mission is still not fully understood. A "defense conversion" program has the aim of converting defense firms and workers from military to civilian production; that is *not* the purpose of TRP. Rather, the TRP mission is to increase defense access to affordable, leading-edge technology by leveraging commercial capabilities and markets. The program pursues this mission in two ways, corresponding to Pillars 1 and 2 of the Department of Defense dual-use technology plan. First, it accelerates the development of emerging commercial technologies, such as flat panel displays and high-density data storage, that are critical to defense. Second, the TRP helps transition defense technologies to commercial applications where that will benefit DoD.

The second approach may be confused with "defense conversion," but the differences are key. The TRP's customer is the Pentagon: The program supports "spinoff" of defense technology only if it preserves access to a technology or makes it more affordable to the military. Moreover, the TRP, in effect, requires defense firms to partner with non-defense firms that have know-how in marketing and low-cost production. Experience has shown that most defense firms cannot "convert" their high-overhead, cost-plus culture to compete in commercial markets. Thus the most effective way to move defense technology into commercial markets is through partnerships with non-defense firms.

Some have questioned the defense relevance of TRP projects in health care, the environment and other seemingly nontraditional areas. In fact, medical technology has long been a mission interest of the military services—e.g., the Army and Navy's research in telemedicine. And environmental technology meets two important defense needs: detection of biological/chemical warfare agents, and monitoring and cleanup of contaminants at DoD sites. More generally, the process for selecting TRP focus areas, evaluating proposals and managing projects ensures that the program serves military needs foremost.

Misunderstandings about the program have led some to characterize the TRP and other dual-use technology programs as a "nontraditional" defense expenditure - that is, an expenditure that does not contribute to traditional DoD military activities. That label is incorrect for two reasons.

First, for 50 years technology has been the basis of this country's military advantage, and defense R&D has been the key to that. The TRP and other DoD dual-use technology programs represent a different—and more effective—way of carrying out certain critical defense R&D activities.

Second, dual use itself has a rich tradition in DoD, particularly ARPA, where program managers in the 1950s and 1960s consciously promoted industrial spinoffs as a way to lower the cost of technology to the military. That visionary approach later fell victim to budgetary pressures as well as political pressures to limit the Pentagon's impact on society (the word "Defense" was added to ARPA's name in 1972, as a way to restrict the agency). The Clinton Administration's supoort for expanded dual-use R&D—like the reinstatement of ARPA's original name—marks a return to the agency's traditional approach.[9]

[9] This history is described in a 1992 article by Admiral Bobby R. Inman and Sen. Jeff Bingaman that urges Congress, for the sake of national security, to "restore the Pentagon's traditional role of promoting technology with commercial as well as military uses." "Broadening Horizons for Defense R&D," *Issues in Science and Technology* (Fall 1992).

One indication of the TRP's success is the amount of private investment it has catalyzed. In 1993, winning projects matched every federal dollar with $1.40 of non-federal funds—$845 million. The cost share by 1994 winners was also significantly above the dollar-for-dollar match required by the TRP. In all, the federal TRP investment of $820 million is leveraging projects worth $1.9 billion. By putting private sector money at risk, the cost share also ensures industry's commitment to the project and lays the foundation for industry to assume the total cost of commercialization.

To provide more systematic feedback, ARPA and the interagency TRP Working Group are developing a formal structure to monitor and assess the impact of the program in terms of its strategic goals. Although it is too early to judge the technical progress of many TRP projects, much less their final outcome, an analysis of the proposals and awards provides a preliminary picture of the program's direction and impact.

Significant Benefits to Defense Systems

The TRP will yield *direct* benefits to the military in the form of technologies and products that the military services can use. *Indirect* benefits include cost savings, advanced commercial capabilities for military use, and preservation of the defense industrial base. (See Chart 1 for sample metrics.)

The TRP has been carefully designed to ensure that military needs are given priority consideration: DoD representatives oversee program planning, and the military services are closely involved in all aspects of program execution.

For example, for the 1993 technology development competition:

- over one-third of the TRP evaluators were from DoD;
- the military services, service laboratories and defense agencies are managing two-thirds of TRP funds;
- service laboratories and other DoD facilities are participants in 30 percent of the projects.

The most persuasive evidence of the military benefit is the projects themselves: All TRP projects meet clear defense needs, as well as contributing to the broader industrial base. Box H (below) describes some typical TRP projects; they are developing dual-use technologies to provide for affordable night vision capability, to improve battlefield casualty treatment, and to make affordable the Army's technically superior, but high-cost, system for locating combat units on the battlefield in real time. By taking advantage of the potential for a commercial market, these projects offer the prospect of technology with improved performance at lower cost to DoD.

As an overview, Chart 2 shows the number and value of 1993 technology development awards in each technology category. (These technology categories are more broadly defined than the focused technology areas in the April 1994 competition.) Three of the 1993 technology development categories contribute directly to the performance and affordability of DoD weapon system platforms: vehicle technologies (including advanced batteries), shipbuilding, and aerospace. These three areas received about 30 percent of available funds. (Chart 3.)

For example, Martin Marietta leads an effort to develop a new airport radar system that can detect hazardous weather conditions while simultaneously monitoring air traffic, using a technology first developed for the Navy. Commercialization of this technology for the civilian aviation market will yield better and cheaper technology to meet military needs in tactical ballistic missile defenses and airborne fire-control systems. To take another example, a Miami-based team led by Pratt & Whitney is developing lightweight, polymer composites for aircraft engines. Advanced composites will significantly increase the performance and range of military aircraft, while lowering the cost of repair and maintenance.

Dual-use process improvements—in electronic design and manufacturing, mechanical design and manufacturing, and materials and structures manufacturing—promise significant improvements in the cost of producing defense systems. (Chart 4.) For example, the Precision Laser Machining Project (Box E, above) will develop a new class of high-speed, high-precision laser machine tools with widespread application to military as well as commercial production. Among other things, these new laser tools will make it possible to increase aircraft fuel savings by several percent, by improving the uniformity of millions of microscopic holes drilled in airframes to reduce wind drag.

Information infrastructure projects, which received 30 percent of 1993 technology development funds, directly enhance defense electronics and communications systems. (Chart 5.) The Gulf War provided a glimpse of the revolutionary potential of these technologies, which can boost dramatically the range and accuracy of conventional weapons such as bombs and missiles, and can design the next generation of aircraft, ships and missiles. In addition to reducing the cost to DoD of information technology through dual-use applications, projects in this category will improve fiber optic transmission, signal processing, radar imaging, wireless communications, and radar frequency modules. Other projects will create new dual-use capabilities such as speech-activated hand-held computers, software standards, and advanced techniques for manufacturing efficiency.

So important is information technology to the military that the April 1994 TRP competition targeted five focused technologies in the information and electronics area. (Chart 6.) One "focus area" is high-density data storage devices. Because commercial needs will eventually drive the market, DoD benefits by stimulating and accelerating that market. Vast increases in portable, low-cost data storage will allow DoD to take full advantage of the growing availability of high resolution mapping images during military operations, and will give our front-line soldiers immediate access to the best information and intelligence. Another group of projects will help ensure the creation of open, interoperability standards for the National Information Infrastructure in areas that are defense-critical. High-definition systems manufacturing technology is a third focus area: These systems (also known as flat panel displays) will be as important to American soldiers in future conflicts as two-way radios and GPS receivers were in Desert Storm.

The 1994 competition also targeted two sensor technologies. (Chart 7.) Uncooled infrared sensors, to take one, offer a potentially affordable approach to providing night vision capability to combat troops; the widespread use of effective infrared devices on the battlefield could revolutionize our ability to fight under cover of night, fog or smoke. The devices now employed by the military require cryogenic cooling, whose cost is prohibitive for widespread use by troops. Commercial development of uncooled sensors—e.g., for police work and enhancement of vision in cars and trucks—could bring improved performance and a tenfold cost reduction for military users (see Box H, below).

Summary: Defense Benefits of "Spinoff" and "Spin-on"

Like uncooled infrared sensors, about half of all TRP projects serve defense needs by moving DoD-funded technologies into commercial applications. Despite the size and sophistication of the defense technology base, the bulk of defense R&D never leaves the defense sector to build commercial capabilities. TRP projects, as Chart 8 shows, are replete with new uses for defense technologies, from the application of amorphous silicon to medical imaging to the use of advanced composites for bridge repair. DoD benefits primarily from the lower costs achieved through more efficient production and economies of scale. In addition, some TRP projects contribute to more than affordability. For example, the work of the Precision Laser Machining Project will yield back a superior technique for jamming the sensors of heatseeking missiles.

Chart 9 summarizes the defense benefits from several TRP projects that "spin-on" emerging commercial technologies. Defense often trails in these technologies; thus the projects provide the military with superior technology that will, over time, become affordable because of the potential for a self-sustaining commercial industry. Flat panel displays and high-density data storage devices fit this pattern. Another example is technology for treatment of battlefield casualties, including digital X-Rays, sensors, and information technology. In one TRP project, General Electric has teamed with EG&G in a two-year program to develop a Digital X-Ray System for Trauma and Battlefield Applications (see Box H, below).

Improvements to Industrial Base Supporting Defense

In addition to providing direct defense benefits, TRP projects strengthen the industrial base supporting defense. The result of these investments will be a stronger and more diverse industrial base capable of making more affordable products for the military. (Chart 10.)

One way the TRP strengthens the industrial base for defense is by expanding the market for defense-dependent firms that cannot sustain themselves by military sales alone. Many of these firms have technologies and core competencies that have application in the commercial sector. Under the TRP, these firms are teamed with commercial firms that understand low-cost production and marketing, to develop viable "spinoffs" for new markets.

Similarly, the TRP is helping to preserve defense-unique capabilities that might otherwise disappear. One example is Hi-Shear Corp., a small Torrance, California, firm that makes military detonators. With the help of a TRP award, Hi-Shear, in partnership with the Torrance Fire Department, is adapting its pyrotechnic technology for use in emergency rescue equipment. By developing new, civilian markets for its technology, Hi-Shear will be able to remain a defense supplier.

Third, a number of TRP projects are spinning off defense technologies that have application to the manufacturing process itself, which enhances the industrial base for defense as well as commercial production. (Chart 11.) For example, DoD's 3D printing capability will be used to increase the precision of injection molding for ceramics, which will reduce the cost of components for commercial and military jet engines; information-related technologies will contribute to more precise computer-controlled manufacturing processes and the "paperless factory." In many cases, the original developer of the technology was aware of the commercial potential but lacked the commercial expertise and financial support that the TRP partnering process provides.

The TRP will be measured in considerable part by its contribution to breaking down the barriers that separate the civilian and defense sectors. Judging from its first two years, the program is succeeding. By design, the TRP has attracted a broad mix of public and private participants and stimulated an enormous amount of collaboration and alliance-building, both within industry, and between industry, universities and federal laboratories. Many losing teams confided that they had gained from the process, and a number of teams said they would proceed without federal funds (albeit on a smaller scale or without as much payoff to DoD).

Most notably, TRP technology development projects bring together teams that are well-integrated, both horizontally and vertically: A typical winning team includes a large defense prime, a large commercial prime, one or more small firms, and a university or federal lab. The presence of commercial firms on most teams is particularly important, because it expands the industrial base serving DoD and ensures that the resulting technology will be commercially viable. In fact, the April 1994 TRP competition, with its emphasis on leading-edge electronics technology, produced a number of awards to teams *led* by commercial firms.

In addition, TRP teams benefit from strong participation by public and non-profit organizations, including universities, medical institutions, public and private laboratories, and government entities at all levels. (Among successful technology development projects, one-third of participants are from outside of industry.) Universities and labs are important sources of advanced technology with potential military application. Government participants often provide the perspective of a non-DoD customer for dual-use technology—as, for example, in the development of equipment for toxic waste clean-up or advanced firefighting services.

The TRP also produced an unprecedented partnership among agencies within the federal government. DoD got the benefit of the other agencies' expertise in civilian technology applications, while the non-defense agencies got valuable exposure to military technologies with potential relevance to their mission needs. For example, the Department of Transportation is now looking at increasing its funding to adapt advanced composites for construction of bridges and roads, which will help to preserve the composites industrial base and bring down the cost of those materials for military aircraft. Cooperation among the agencies has increased outside of the TRP, as a result of their greater awareness of one another's activities in dual-use technology. Of lasting value, the civilian agencies have begun to adopt ARPA's more streamlined approach to funding R&D, including greater flexibility toward intellectual property rights.

Lessons Learned. The TRP's 1993 competition revealed two key areas for improvement: The success rate of proposals was too low, resulting in wasted bid and proposal expenditures by unsuccessful applicants. And participation by small firms was too limited.

To raise the success rate for TRP applicants, the 1994 competition targeted specific technology focus areas that are of direct military interest. Among other advantages, this targeting gave prospective applicants a better basis for deciding whether to apply. Second, the TRP conducted more outreach to prospective applicants, including day-long workshops on each technology focus area. Third, prospective teams were encouraged to submit "white papers" for review, prior to preparing a full proposal. As a result, although requested funds still exceeded available funds by a factor of four overall, the success rate of technology development proposals was 18 percent, which is more typical of other ARPA programs.

To improve the ability of small companies to participate, the TRP took advantage of new legislation permitting small firms to use SBIR grants as part of their cost share. Small firms also were given up to 120 days following the announcement of an award to come up with their share of project costs. These changes, combined with a more aggressive outreach effort to small firms, resulted in a higher participation rate: 70 percent of the 1994 development teams included one or more small firms, compared to 50 percent in 1993.[10]

In addition to these changes, the TRP has increased the level of involvement by the military services even more, to ensure that technologies developed with program funds are rapidly integrated into defense systems. The services played a larger role in the selection of focus areas for the 1995 competition, and they are now represented formally on the Defense Technology Coordinating Council, which oversees the TRP.

1995 Competition. The Clinton Administration is committed to continuing and to improving the TRP. Program staff have conducted workshops around the country both to provide feedback to unsuccessful applicants and to solicit ideas for improving the program. The TRP held several two-day workshops to help participants form and maintain R&D partnerships.

The 1995 competition, announced on October 21, 1994, will allocate $415 million in matching funds; the bulk of the money will go to technology development projects in 12 dual-use focus areas selected for their defense relevance:

- **Digital wireless communications and networking systems**—Development of innovative communications and networking products to promote the "digitization of the battlefield."
- **Affordable polymer matrix composites for airframe structures**—Development of materials and manufacturing technologies for affordable fabrication of primary airframe composite structures to improve military and commercial aircraft performance and cost-effectiveness.
- **Microelectromechanical systems (MEMS) applications**—Demonstration and insertion of MEMS technology into defense and commercial applications (inertial sensors, embedded detection devices, etc.).
- **Low-cost specialty metals processing**—Demonstration and insertion of innovative forming of component fabrication processes to make specialty metals more affordable for military and commercial use.
- **Millimeter wave products**—Development of affordable and reliable millimeter wave products using monolithic-format integrated circuits for use in military and commercial applications.
- **Electric and hybrid tactical and commercial vehicles**—Development of affordable medium-to-heavy hybrid electric drivetrains for military and commercial use.

[10]Overall, small firms have done best in the TRP competition as participants rather than project sponsors. This reflects DoD's strong preference for project teams that are committed to commercialization: Many small technology-oriented firms lack commercialization and production know-how, and TRP proposals led by small firms often have not included other firms with compensating expertise.

- **Operations other than war/law enforcement**—Development of affordable, prototype equipment, such as remote metal detectors and body armor, that meets special mission requirements of both military services and law enforcement agencies.
- **Ceramic material applications**—Demonstration and insertion of high performance ceramics and ceramic composites to enhance performance and decrease weight of military and commercial vehicles, aircraft and other systems.
- **Small precision optics manufacturing technology**—Development of cost-effective processes for manufacturing optical components for remote sensing and surveillance systems and other military and commercial systems.
- **Affordable controls technologies**—Development of affordable, advanced digital electronics and control technologies for enhanced military systems and industrial automation.
- **Cryogenic coolers for electronic systems**—Development of reliable and low-cost cryocoolers for electronic systems.
- **Biological sensors and multiorgan diagnostic screening**—Development of non-invasive sensors for physiological parameters and non-invasive multiorgan screening technologies suitable for military health care requirements under combat or peacetime conditions.

Additional information about the current TRP competition is available by calling 1-800-DUAL-USE.

BOX H

Selected TRP Projects: Dual-Use Technology to Meet Defense Needs

Infrared Sensors

A major contributor to the U.S. ground victory in Desert Storm was cryogenically cooled infrared sensors. Through the use of these sensors, our forces "owned the night." Unfortunately, cooled sensors are too expensive for wide adoption by combat forces. A simpler and inherently less expensive alternative is uncooled infrared sensors. Although they lack the great sensitivity and range of the cooled version, they could still be adequate for many uses, and they are a high priority for the military.

Despite their cost advantage, uncooled sensors are at this point still too expensive for wide use, and they require upgraded performance as well. If better performance and lower costs are achieved, an array of choices will be open to the military user. They range from embedded sensors in missile terminal guidance systems, to "lights out" night driving, to equipment for the Twenty-First Century Warrior—an armored infantryman outfitted with night goggles and rifle sights that depend on infrared sensors. The widespread use of effective infrared devices on the battlefield could revolutionize our ability to fight under cover of night, fog or smoke.

Lower costs and better performance look technically feasible, but to get from here to there, research and development is necessary. Yet the present market for infrared sensors (mostly military) is too limited to support much R&D; companies making the devices plan to cut or eliminate R&D, unless wider sales are in view. The potential commercial market is sizable—probably as much as 100,000 units a year, compared with current (mostly military) sales of 6,000 to 10,000 per year. Civilian uses could include detecting roof hot spots (indicating heat loss), finding power line leakages, seeing through smoke during fires and, eventually and most significant, an aid for all night drivers. But those uses are mostly potential. Although a few devices have been sold for such purposes, they are the cooled military version and are too costly for a wider market.

The TRP Infrared Sensor project is aimed at improving performance and lowering costs at least tenfold through commercial approaches to development and eventually—assuming growing commercial sales of a reasonably priced device—through economies of scale. As costs fall and the market expands, the armed services can meet their needs from an integrated civilian-military base, adding its particular requirements to purchases from an active industry.

TRP projects are supporting three different technical approaches for improvement of uncooled infrared sensors, in teams led by Loral, Texas Instruments, and a smaller company, Inframetrics.

BOX H (cont.)

Casualty Care

The first hour after injury on the battlefield is critical. A wounded soldier's chance of recovery depends profoundly on whether he receives a prompt diagnosis and care. The proportion of wounded who survive this "Golden Hour" has not altered since the Civil War.

Two strands in modern technology offer the opportunity to greatly improve the proportion of survivors. The first is sophisticated sensors and displays that allow accurate monitoring of the injury, the condition of internal organs, and a diagnosis. The second is modern information systems, and their management and distribution. TRP projects support development in both of these areas.

The goal is for every soldier going into combat to have sensors and an identifier (like a bar code) in place. If the soldier is wounded, sensor/communication/display systems can bring to doctors away from the battlefield the information needed for diagnosis, and instruction for treatment can be relayed to medics on the spot. Using the system, doctors at a distance can determine which of the wounded need most immediate attention. The system virtually puts a physician at the side of the wounded soldier. Through the individual identifier and a data storage system, information on a soldier's history and condition can follow him from the battelfield to the MASH unit to a hospital in the United States.

Remote diagnosis and linkage can also help paramedics save civilian lives at the scene of accidents. As for information systems, it is estimated that 20 percent of U.S. health care costs go for activities directly related to the handling of information. An efficient data storage and retrieval system could substantially reduce these costs.

The TRP projects on casualty care would meet military needs while also integrating civilian and military medical technologies more fully. For several reasons, integration is imperative. First, civilian emergency teams and hospitals can work with the emerging technologies on a daily basis, providing new data and feedback on design and use. Military use, on the other hand, will be confined mostly to training, only rarely (it is hoped) to actual conflict. Second, military casualty care systems must be compatible and interoperable with civilian systems, since the military is increasingly dependent on the civilian health care system for trained people (e.g., consultants and reservists). Finally, in common with other projects, the efficiencies of scale in a large market, such as the health care industry, will reduce the cost of the new technologies, making them more affordable for the military.

A project on a Digital X-Ray System for Trauma and Battlefield Applications is part of the TRP approach to casualty care. General Electric has teamed with EG&G in a two-year program to develop such a system. It will allow direct digitization of the X-Ray, with no use of film, and will enable immediate transmission of the X-Ray to doctors remote from the battlefield or accident scene. Besides this advantage, digital imaging has better resolution and contrast than film. It reduces storage problems, eliminates hazards from photographic chemicals, and solves the problem of 30 percent loss of X-Ray film during storage and transport. Besides its great benefits for wounded soldiers and injured civilians, digital X-Ray promises a competitive advantage for GE by the year 2000.

BOX H (cont.)

Advanced Automatic Train Control System

The purpose of this TRP award is to develop the Army's future command, control, and position location technology for use in civilian transit systems—and in turn, to greatly reduce the cost of the system to the military. The sequence is this: 1) spinoff of military-invented technology to a civilian application; 2) significant lowering of the cost through the use of commercial design and production technology and the economies of scale gained from a much bigger market; and 3) "spin-on" that returns the benefit of lower cost to the military—with the likelihood of still lower costs as the civilian market grows.

This sequence is not just a hypothetical possibility. It has already happened with other military-based technologies that have gained the advantage of production in an integrated military-civilian industrial base. For example, Delco Electronics and Hughes Aircraft (both subsidiaries of GM Hughes Electronics), formed a joint venture to produce on the same line the FOREWARN system for school buses, and the military system on which it was originally based, the Air Force's MIMIC-based phased-array radar sets for fighter airplanes. For the military, the benefit is substantially reduced costs, and for the civilian side, access to a life-saving technology for school children (see Box D).

TRP's Advanced Automatic Train Control project is aimed at similar benefits. It is based on the Army's Enhanced Position Location Reporting System, which is designed to enable commanders on the battlefield to collect location and other information automatically, in real time, at the unit level. This sytem is much better technically than any competing system, especially in network management. But its cost is extremely high. If the TRP project succeeds as expected in applying the technology to rapid transit systems, costs will fall at least 40 percent, and it will become affordable for the military.

The team working on commercialization of this Army technology consists of the San Francisco Bay Area Rapid Transit (BART) District; Hughes Aircraft Company, which developed the military version; and the Morrison Knudsen Corporation, which makes equipment for BART and other rail systems. The team expects the system it is developing to provide the precise location of each train, even in tunnels; to operate with less distance between trains, thus doubling passenger carrying capacity in rush hours; to offer unprecedented safety, reliability, and ease of retrofit; and to cost half what conventional systems cost.

There is a good commercial market for train control systems worldwide. Currently, the global market is about $400 million, and it is expected to grow to about $2 billion within a decade. Unfortunately, the market is dominated by foreign suppliers; one U.S. supplier has only a small piece of it. With a much superior system based on Army technology (which has to meet the Army's tough demands for a reliable radio system with anti-jam features), American suppliers could have a real chance to crack the world market.

This TRP project offers triple threat advantages: a technically superior, affordable system for the Army; a competitive opportunity for U.S. producers; and better service and greater safety for subway riders.

Chart 1
Sample Metrics – Defense Benefits from TRP

"Process"– Analysis of Proposals and Awards

- Level of investment in areas critical to defense
- Development of technologies that will result in defense products
- Dual-use investments that will reduce defense costs
- Increased availability/security of defense material
- Infuse military items with advanced commercial technologies

Technical Progress and Commercialization

- On time progress toward technical milestones for defense applications
- Transfer of technology and expertise within team
- Identification and coordination with potential defense customers
- Progress toward commercializing product for DoD market

Outcome – Analysis of Results

- Breadth and criticality of military applications
- Cost savings achieved through dual-use approaches
- Increases in DoD use of commercial technologies and items
- Impact of "spinoffs" on defense costs
- Preservation of defense industrial base, skills, processes and facilities

Chart 2
Improved Capabilities for Defense

TRP enhances defense through investment in weapon system platforms, as well as essential information infrastructure and manufacturing technologies.

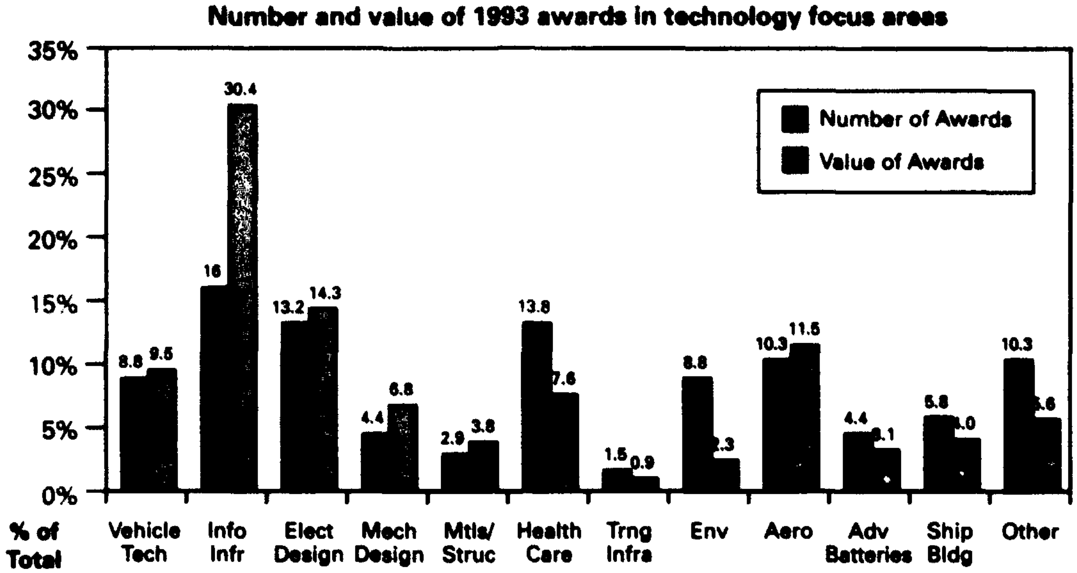
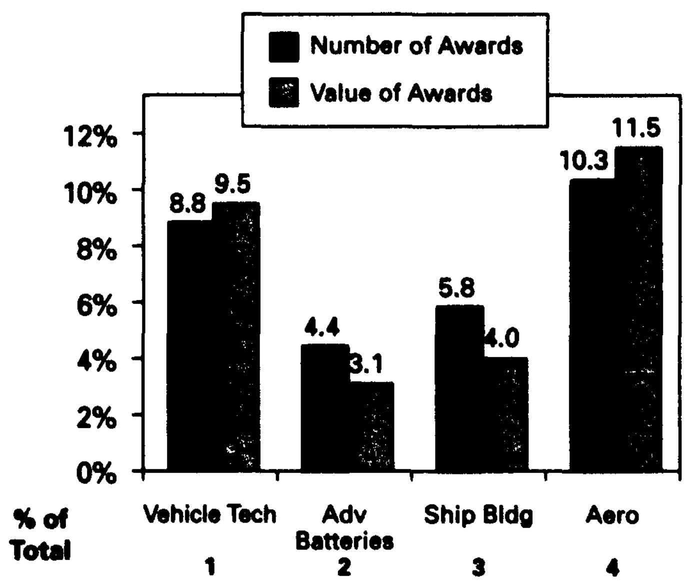


Chart 3
Impact on Performance and Affordability of Weapon System Platforms



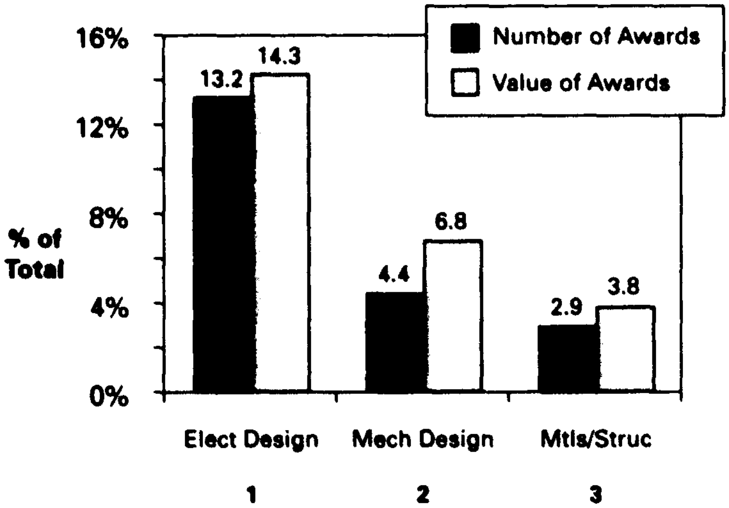
1 **Vehicular Technology** (Gov't Share $29 M)
Examples: motion sensing systems, hybrid rocket motors, electric vehicle powertrain, turboalternators–hybrids

2 **Advanced Batteries** (Gov't Share $9.6 M)
Examples: lithium rechargeable, solid polymer

3 **Shipbuilding Infrastructure** (Gov't Share $12.2 M)
Examples: robotics for non-repetitive operations, propulsion technology transfer, submerged cargo pumping, advanced ship repair

4 **Aeronautical Technologies** (Gov't Share $35.4 M)
Examples: real-time winglift monitoring, guidance system – safe takeoff/landing in bad weather, electric actuator and control system, precise fuel control, low-cost "fly by light" systems

Chart 4
New Design and Manufacturing Capabilities for Defense



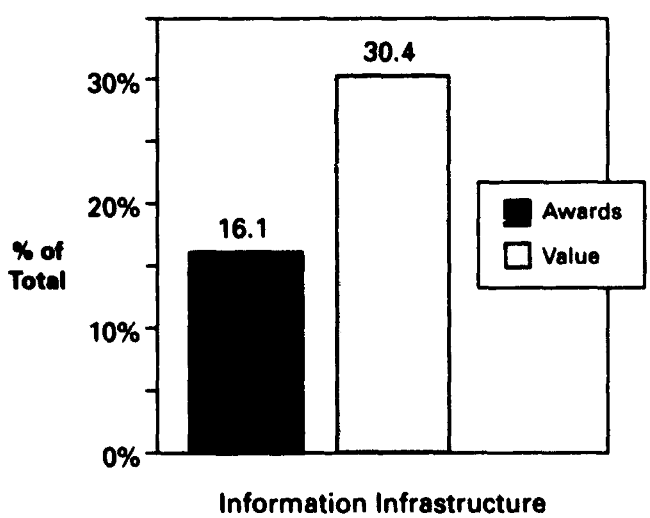
1 Electronics Design and Manufacturing
(Gov't Share $43.7 M)
Examples: integration of micro devices, optoelectronics for wireless comms, in-situ process sensors and controls, optoelectronic modules, low-cost semiconductor interconnects, advanced sensing optics for manufacturing

2 Mechanical Design and Manufacturing
(Gov't Share $20.9 M)
Examples: precision laser machining, hydrostatic bearings, just-in-time maintenance

3 Materials and Structures Manufacturing
(Gov't Share $11.8 M)
Examples: composites for aircraft propulsion, high-performance tooling

***Plus...** Additional defense benefits from investments in environmental technologies ($7M), casualty treatment ($23.4M), training ($3M) and other technologies ($17.3M), including phased-array radar, optics, and high-temperature superconductivity*

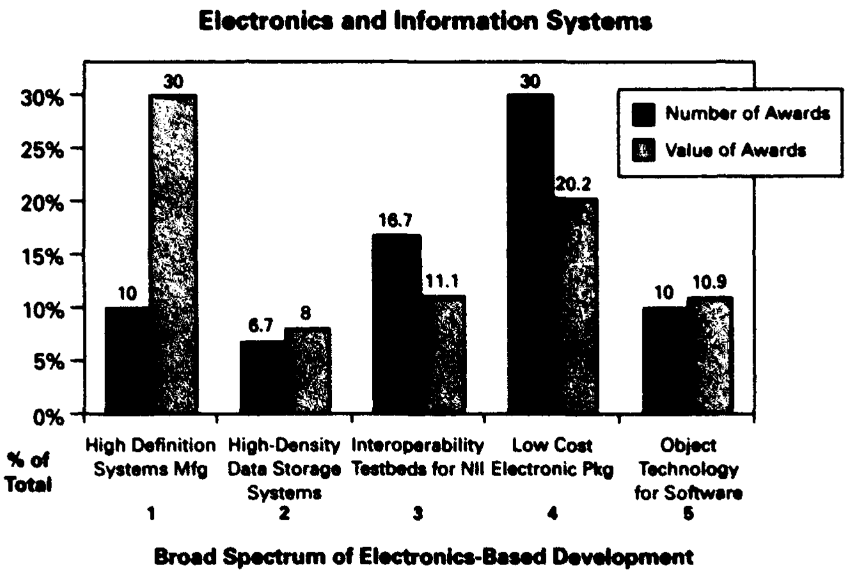
Chart 5
Innovations in Defense Electronics and Communications



Information Infrastructure
(Government Share $93.2 M)
Largest single area of TRP investment—communication networks and information services for military (and commercial) applications

Illustrative TRP Projects
- High speed fiber optic transmission
- Speech-activated hand-held computers
- Cost-reducing sensor and communications applications for MIMIC technology
- Multi-media signal processors
- Software standards for enterprise integration
- Improved infrared and radar imaging systems for all-weather use
- Next-generation wireless communications transmitter
- "Head-mounted" display for manufacturing efficiency
- Low-cost radio frequency modules for communications networks

Chart 6
1994 Awards – Advanced Technology and Reduced Costs for Electronics, Communications and Information Systems



1 **High Definition Systems Manucacturing**
- Improved EL displays for DoD
- Manufacturing technology for field emission displays (FED)

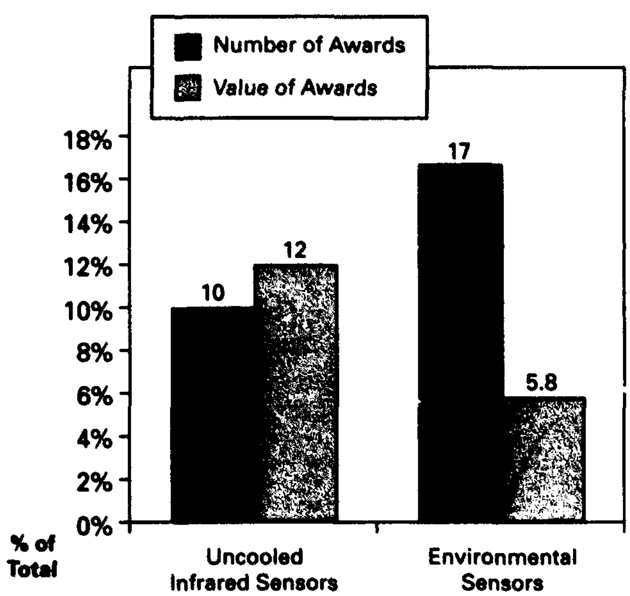
2 **Prototype Data Storage Systems**
- Increase optical system throughout and capacity (by factor of 5-10)
- Portable magnetic disk info system for field

3 **Interoperability Testbed**
- Develops tools, standards and procedures for NII–begun as DoD's ARPANET
- Networks for air-and ground-based elements
- Intelligent information retrieval

4 **Low-Cost Electronic Packaging**
- "Rugged" packaging for vehicles & aircraft
- "Flip chips" to replace wire bonding
- New ceramic packaging for wireless comunications

5 **Object Technology**
- Reusable software components & services

Chart 7
1994 Awards – Affordable Sensors



Uncooled Infrared Sensors
Enhances night-vision capability of U.S. forces through reduction of cost and technological impediments

- New sensor technologies with advantages over current sensors (monolithic microbolometer)
- Expansion of sensor applications and markets to lower defense cost

Environmental Technologies
Rugged sensors to detect environmental contamination are an urgent requirement—for both military and commercial spheres.

- In-situ, real-time detection of groundwater contaminants
- Remote capability to detect volatile organic compounds, including chemical and biological warfare agents
- Remote system to monitor emissions and map aerosols in atmosphere
- Deployable system to detect volatile compounds in field

Chart 8

Benefits of Commercializing DoD Technologies

Many TRP projects "spin off" defense technologies to strengthen important defense producers and lower the cost to the military.

DoD Technology	Commercial Benefits	Defense Benefits
Uncooled infrared sensors	Night driving assistance Security surveillance Collision avoidance systems Locating power and thermal leaks	Order of magnitude lower cost for night vision technology
Integrated millimeter wave radar/ infrared sensor for landing guidance system	Airline safety during inclement weather	Enables military use of poor landing strips for combat support.
Lasers	Laser machining (improved precision in cutting and welding, less machining required)	Improved low-rate production of military systems (e.g., military aircraft, ship, vehicle production). Lasers for "blinding" sensors of incoming missiles
Acoustic signal processing and diagnostics	Just-in-time maintenance on shafts, power generation systems (turbines, generators)	Replacement of critical helicopter rotor components prior to failure
Enhanced Position Location Reporting System	Advanced automatic train controls	40% cost reduction in battlefield location system
Fly-by-light	Alternative to fly-by-wire	Invulnerability to electro-magnetic pulse, RF interference
Pyrotechnics	Rescue equipment	Preserve on-shore defense industry
Amorphous silicon technology	Medical imaging	Battlefield casualty diagnostics, teleradiometry
Nuclear submarine valve technology	Zero emission control valves (e.g., refineries, chemical transport)	Reduce cost, preserve supplier
Avanced polymer composites	Bridge, infrastructure repair	Availability, affordability for high performance advanced composities; portable tactical bridges

Chart 9
Leveraging Commercial Technologies for Defense

TRP "spin-on" projects provide the DoD with superior technology that will be sustained by dynamic commercial markets.

Commercial Technologies	Defense Benefits
Electric and hybrid propulsion (e.g., turboalternators, propulsion systems)	Enabling technology for armored, tactical vehicles (acceleration, rough terrain capability, on-board power, silent running, fuel efficiency, design flexibility)
Advanced batteries	Reduce logistical burden from increased demand for portable electric power on battlefield
Healthcare technologies (digital X-Rays, telemedicine, noninvasive organ sensors/diagnostics, oxygen generator, biological modeling)	Trauma care under battlefield conditions to save lives through intervention during "golden hour"; virtual physician presence; measurement/transmission of vital signs
C4I (self healing networks, voice recognition systems, spacial division multiple access technology)	Affordable, updatable, high bandwidth, wireless networks to serve highly mobile stations
Nuclear, biological and chemical detection (infrared and ultraviolet sensors; mass spectrometry; chemical and biological agent sampling, collection, and mapping)	Accurate detection and remote monitoring for chemical and biological agents
Electronics design and manufacturing (optoelectronics, low-cost packaging)	Ability to integrate optical information into electronics systems; affordability through adopting commercial, low-cost electronic packaging techniques
Ultrasonics	Ability to determine aircraft wing icing potential prior to takeoff; particularly applicable to secondary airfields

Chart 10
Sample Metrics – Industrial Base Benefits from TRP

"Process"– Analysis of Proposals and Awards

- **Number of non-defense/non-traditional participants**
- **Defense firms maintaining viability through "spinoffs" to new markets**
- **Non-defense firms entering defense market through "spin-ons"**
- **Development of effective partnerships among diverse organizations**
- **Likelihood of improved health in essential defense sectors**

Technical Progress and Commercialization

- Effective coordination of responsibilities among partners
- Progress toward product that responds to diverse market needs
- Transfer of knowledge and expertise between participants
- Progress toward commercialization

Outcome – Analysis of Results

- Increase in diversity within defense supplier base
- Transition to integrated facilities
- Expansion of market/improved viability of defense-dependent firms
- Increase in use of dual-use and/or commercial products by DoD
- Expansion of privately funded TRP-like activity

Chart 11
Application of Defense Technologies to Improve U.S. Manufacturing

Defense Technology	Improved Manufacturing Process
Sensing optics	Process control & inspection of circuit boards
"Best Manufacturing Practices"	Shipyard manufacturing improvements
3D printing	Injection molding (ceramics)
In-situ process control	Growth of electronic materials
Advanced adhesives	Interconnects for flip chip attachment
Computer based tools	Generation of instructional materials
Robotics	Portable welding system for ships
Vision computers	Vision-capable robotics
Lasers	Laser machining
Software	Software standardization for manufacturing